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Dental disease in alpacas. Part 1: Prevalence of dental disorders and their mutual relationships

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Abstract

Background: Dental disease is a troublesome health concern in alpacas. Specifically, the occurrence of tooth root abscesses has been described in veterinary literature. Nevertheless, no objective prevalence data are available for dental disorders in alpacas.

Hypothesis/objectives: To determine the prevalence of dental disorders in alpaca herds in Belgium and the Netherlands. To study the associations between the different dental disorders encountered in alpacas.

Animals: A total of 228 alpacas (*Vicugna pacos*) originating from 25 farms.

Methods: This is a cross-sectional study. Dental disorders were diagnosed by dental examination of sedated animals using a dental mirror or a portable rigid oroscope.

Results: At the animal level, 82% (n = 187) had dental disorders of which 74.6, 41.7, and 3.9% were cheek teeth, incisor disorders, and canine disorders, respectively. At the level of the cheek teeth, diastemata (43.1%) were most common, followed by wear abnormalities (WA; 39.6%) and periodontal disease (PD; 33.3%). A significant association was detected between the presence of diastemata and PD (odds ratio [OR], 13.1; 95% confidence interval [CI], 6.6-27.7; $P < .001$). Pulp exposure was significantly associated with the presence of diastemata (OR, 11.8; 95% CI, 3.8-51.5; $P < .001$), PD (OR, 8.2; 95% CI, 3.1-25.3; $P < .001$) and WA (OR, 2.9; 95% CI, 1.2-7.4; $P = .002$).

Conclusion and Clinical Importance: Dental disorders are highly prevalent in alpacas in Belgium and the Netherlands. Several dental disorders in alpacas had significant associations. To prevent the development of advanced stages of dental disease, routine dental examinations are advised to allow early detection and prompt treatment.

KEYWORDS

apical infection, cheek teeth, diastemata, New World Camelids, periodontal disease, tooth root abscesses, wear abnormalities

Abbreviations: CI, confidence interval; OR, odds ratio; PD, periodontal disease; WA, wear abnormalities.

1 | INTRODUCTION

Dental disease is commonly reported as a troublesome health concern in New World Camelids.[1-4] The hypsodont dentition in alpacas (*Vicugna pacos*) shows most similarities with the dentition seen in ruminants, but also bears strong resemblance to equid dentition. Dental disorders such as tooth root abscesses, periodontal disease (PD), malocclusions, tooth fractures, uneven teeth, overgrown teeth, worn teeth, and retained deciduous teeth have been described in this species.[1] Tooth root abscesses, recently termed "(peri)apical infections," are reported as the most common dental condition in llamas and alpacas.[1,5,6] Studies in other herbivorous species indicate a high prevalence of dental disorders and associated clinical signs.[7-18] The location and specific prevalence seem to be highly dependent on the species studied and study design. To date, detailed objective prevalence data are not available for dental disorders in alpacas. Few alpacas diagnosed with an apical infection show obvious signs of oral discomfort during mastication, despite already suffering from an advanced disease process.[1] Alpacas are known to conceal clinical signs and often only show weight loss in the more advanced stages of the disease process, making treatment more challenging. Earlier detection of the disease phases preceding apical infection would be beneficial for animal welfare, medical, and economic reasons. Apical infections have been associated with PD in 60% of cases and with a patent infundibulum in 20% of cases. The remaining 20% of apical infections were of unknown cause.[5] Associations between different dental disorders have been investigated and proven to be of importance in other species. These associations have led to better insight into the course of different stages of dental disease in these species.[8,19,20] Nevertheless, details on the etiopathogenesis of dental disease in alpacas largely remain unknown. We aimed to obtain overall and within herd prevalence estimates of specific dental disorders in alpacas housed on farms in Belgium and the Netherlands. A second objective was to identify possible associations between the different detected dental disorders in alpacas.

2 | MATERIAL AND METHODS

2.1 | Study design

A cross-sectional study was conducted on alpaca farms located in the northern part of Belgium and the southern part of the Netherlands. To avoid interference with gestation, the study was done between June and October 2018. Participants were selected from the members list of the Alpaca Association Benelux in May 2018 (n = 215 herds) after a positive response to the invitation they received. Out of 33 interested farms (response rate, 15.3%), 25 farms were conveniently selected based on traveling distance (95% confidence to obtain a prevalence estimate with an accepted error of 10%). The number of animals to be examined at each farm was selected by the owner depending on their economic value and the gestational status of the female animals.

2.2 | Clinical examination and data collection

Dental examinations were performed after deep sedation using a combination of ketamine (5 mg/kg IM, Ketamidor, Richter Pharma, Austria) and medetomidine (30 μg/kg IM, Sedator, Eurovet, Bladel, Belgium) or dexmedetomidine (15 μg/kg IM, Dexdomitor, Orion Corporation Orion Pharma, Espoo, Finland). The oral cavity was irrigated thoroughly to evacuate food particles. A miniature pony speculum was applied, combined with a dental speculum light. A custom-made dental chart was completed for each animal after examination of teeth and surrounding soft tissues using a dental mirror, a rigid portable endoscope (Karl Storz, Tuttlingen, Germany) or both. Individual teeth were identified using the modified Triadan system.[21] Dental disorders were defined as any deviation in the normal dentition at the level of the incisors, canines or cheek teeth. Specific cheek teeth disorders were described, and identification criteria were established (Table 1). The number, location, and specific characteristics of all encountered disorders were recorded. All dental examinations were performed by the same 2 investigators (K. Proost and L. Vlaminck).

2.3 | Statistical analysis

The unit of analysis was the individual animal. Overall and within herd prevalence were determined as described previously.[26] Animals were divided into 5 age categories: Group A (0-3 years), Group B (3.1-6 years), Group C (6.1-9 years), Group D (9.1-12 years), and Group E (12.1-17 years). Statistically significant differences over the different age categories for different cheek teeth disorders and associations between different specific dental disorders were determined by performing univariate logistic regression analyses with herd added as a random factor to account for clustering (glmer). Significance was set at $P < .05$ using R V3.5.2 (R foundation for statistical analysis) for statistical analyses.

3 | RESULTS

3.1 | Study population

A total of 228 alpacas originating from 25 different farms were included in the study. The mean number of animals examined per herd was 9 ± SD 7, ranging from 1 to 28. Average sampling rate was 40.6% (range, 2.9%-93.3%). The study population included 115 (52.4%) female, 51 (22.4%) male, and 62 (27.2%) male castrated animals. The age of the alpacas included in the study ranged from 1 to 17 years (5.60 ± 3.17 years). The majority of included animals belonged to the Huacaya breed (223/228, 97.8%), whereas the remaining 5 animals were Suri alpacas.

3.2 | Farm-specific prevalence

Average within herd prevalence of dental disorders was 85.1% ± 18.5% (range, 22.2%-100%) as depicted in Figure 1. The mean within

TABLE 1 Definitions of detected specific dental disorders

Dental disorders	Definition
Diastemata	Abnormal space between adjacent teeth that should normally be in contact. These diastemata could be present with or without food impaction. Some cases with very narrow interdental spaces only allowed the entrapment of a few blades of grass.[22]
Wear abnormalities	A deviation from the normal appearance of the occlusal surface. With the aforementioned definition, a differentiation could be made between a normal wear pattern and worn teeth, shear mouth, wave mouth, step mouth, enamel overgrowths, focal overgrowths, accentuated transverse ridges, and overgrown incisor teeth. Individual definitions were used to describe the characteristics of these specific wear abnormalities.
Worn teeth	Teeth which underwent advanced wear. This could vary from senile excavation (loss of infundibula at the level of the cheek teeth) and resultant excessive wear of the central part of the tooth, to teeth fully worn down to the gingival margin. No differentiation could be made between advanced wear which occurs because of normal aging and pathological accelerated wear given the lack of scientific evidence.
Wave mouth	The presence of an undulating occlusal surface of the cheek teeth in a rostro-caudal direction.[23]
Shear mouth	Excessive occlusal angle of cheek teeth along the occlusal table.[12]
Step mouth	A super-eruption at the level of the cheek teeth, usually comprises only one element opposing a missing tooth.[23]
Enamel overgrowths	Sharp buccal maxillary and lingual mandibular cheek teeth overgrowths comprising calcified dental tissues.
Focal overgrowths	Localized rostrally/caudally maxillary/mandibular cheek teeth overgrowth.
Accentuated transverse ridge	Locally overgrown transverse ridge on a cheek tooth, mostly opposing a diastema.
Overgrown incisors or canines	Specific incisors/canines protruding beyond the normal occlusal plane. At the level of the incisors often seen in combination with a mandibular overbite.
Periodontal disease (PD)	PD is defined as an inflammatory condition of the tissues surrounding and supporting the teeth. Different degrees of severity were recognized ranging from mild gingivitis (gingival swelling, reddening) to more severe interproximal gingival retraction up to deep periodontal food pocketing, increased tooth mobility, and fistulation often associated with drainage of pus.
Malpositioned teeth	Malposition in a buccal or lingual/palatal direction at the level of the cheek teeth. Malpositioning at the level of the incisor teeth was noted in case of abnormal implantation of the incisors or canines to a more lateral, mesial, rostral, or caudal level. Partially rotated incisor teeth were also included in this category.
Occlusal pulpar exposure	A defect in the secondary dentin of the occlusal surface leading to pulpar exposure, often characterized by dark discoloration of the surrounding dentin.
Persisting deciduous teeth	Teeth persisting longer than normally expected as described by the available tooth eruption data.[24] Furthermore, malpositioned teeth in the presence of their respective permanent elements at their normal position were considered persisting, disregarding eruption times of the permanent dentition.
Tooth fractures	Fracture of the clinical crown. Different fracture configurations were recognized including sagittal fractures, slab fractures involving one or more dental stars, and simple chip fractures.
Focal gingival recession	Proximal deviation of the gingival margin adjacent to a certain element. No deviations in the interproximal space.[25]
Missing teeth	If fewer teeth were present than could be expected based on the classical dental formula of alpacas. Only teeth with an expected prevalence of 100% were classified as "missing."
Infundibular caries	Carious lesions (erosion and dark discoloration) of the enamel at the level of an infundibulum at the level of the cheek teeth. Extension into the adjacent dentin possible.[12]
Peripheral caries	Carious lesions (erosion and dark discoloration) of calcified dental tissue on the nonocclusal aspects of the clinical crowns.
Supernumerary teeth	Teeth additional to the normal series.
Mandibular overbite	Absence of occlusion at the level of the incisors and the dental pad. The lower incisors protrude in a rostral direction beyond the rostral margin of the dental pad. An evaluation could only be correctly made in individuals were no corrective odontoplasty had been performed previously.
Mandibular underbite	Absence of normal occlusion at the level of the incisor teeth. The occlusal surface of the mandibular incisors lies in a more caudal position against the dental pad.
Calculus	Also known as tartar. Calculus is formed by calcification of a bacterial plaque. It can be defined as a hard mineralized substance which is firmly attached to the underlying tooth surface. No objective assessment was performed to evaluate the extensiveness of calculus deposition.

herd prevalence of diastemata, PD, defects in the secondary dentin indicative of pulp exposure, persisting deciduous teeth, and malpositioned teeth were 43.0% ± 22.8%, 32.9% ± 24.6%, 13.9% ± 21.8%, 10.9% ± 20.0%, and 21.2% ± 25.3%, respectively. Within herd prevalence of each aforementioned specific dental abnormality ranged from 0 to 100%.

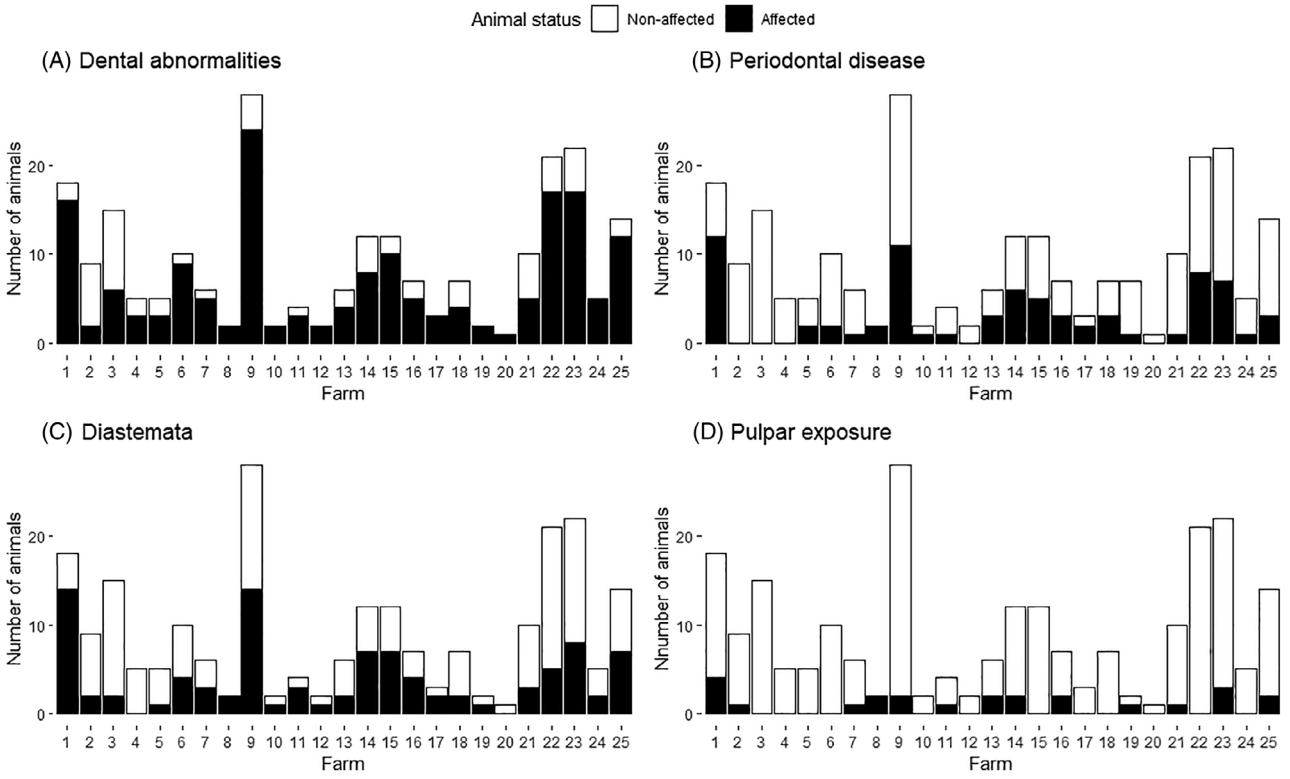

FIGURE 1 Farm specific representation of the number of affected animals diagnosed with dental disorders in general (A), periodontal disease (B), diastemata (C), and occlusal pulpar exposure (D), specifically, over the total number of included animals

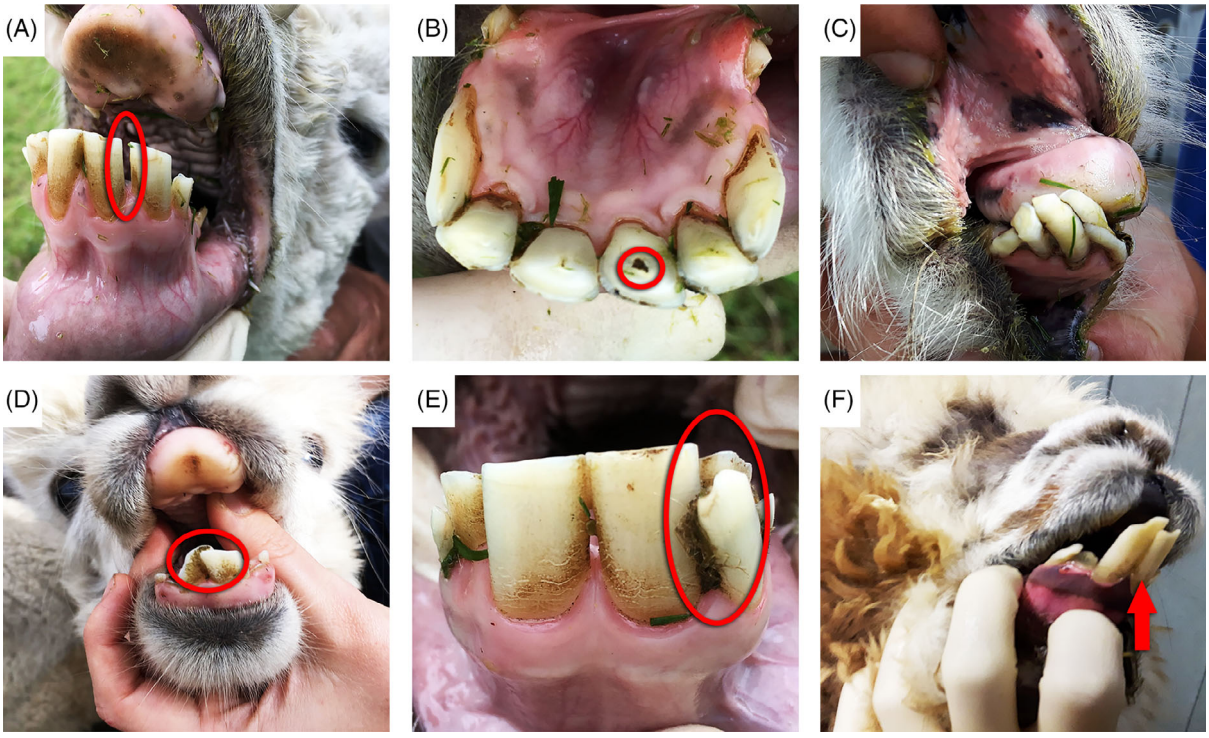

FIGURE 2 Lesions noted at the level of the incisors: A, open diastema between Triadan 301 and Triadan 302; B, defect in the secondary dentin indicative for pulpar exposure at the level of element 301; C, malpositioned incisor teeth causing abnormal wear; D, malpositioned permanent incisor teeth in a 3.3-year-old alpaca; E, persisting deciduous Triadan 702; a permanent 302 has erupted in a lingual position; F, mandibular overbite resulting in severe overgrowth of Triadan 301 and Triadan 401

TABLE 2 Prevalence (%) and number of affected animals (n) of specific incisor or canine disorders with their mandibular/maxillar distribution

Incisor and canine disorders	Prevalence maxilla	Triadan position	Prevalence mandibula	Triadan position
Diastemata	0	-	15.8% (35)	01-01 (23), 01-02 (29), 02-03 (12)
Occlusal pulp exposure	0.8% (2)	03 (4)	11.0% (25)	01 (33), 02 (20), 03 (3)
Malpositioned teeth	0.4% (1)	04 (2)	10.5% (24)	01 (20), 02 (8), 03 (12), 04 (1)
Wear abnormalities	0.4% (1)	03 (2)	9.2% (21)	01 (19), 02 (5), 03 (1), diffuse (7)[a]
Periodontal disease	0	-	3.9% (9)	01-01 (7), 01-02 (3), 04 (1)
Mandibular overbite	0	-	3.5% (8)	-
Crown fracture	0.4% (1)	03 (1)	2.6% (6)	01 (5), 02 (3), diffuse (1)[b]
Persisting deciduous teeth	0	-	0.8% (2)	01 (1), 02 (1), 03 (2)
Mandibular underbite	0	-	0.8% (2)	-
Missing teeth	0	-	0.4% (1)	01 (2)
Peripheral cemental cariës	0	-	0.4% (1)	01 (1)
Calculus	0	-	1.3% (3)	04 (6)

Note: The location of each abnormality is reported on a tooth/interproximal level.
[a]Wear abnormality including all mandibular incisors.
[b]Multiple small enamel fragments (chip fractures) missing at the level of all mandibular incisors.

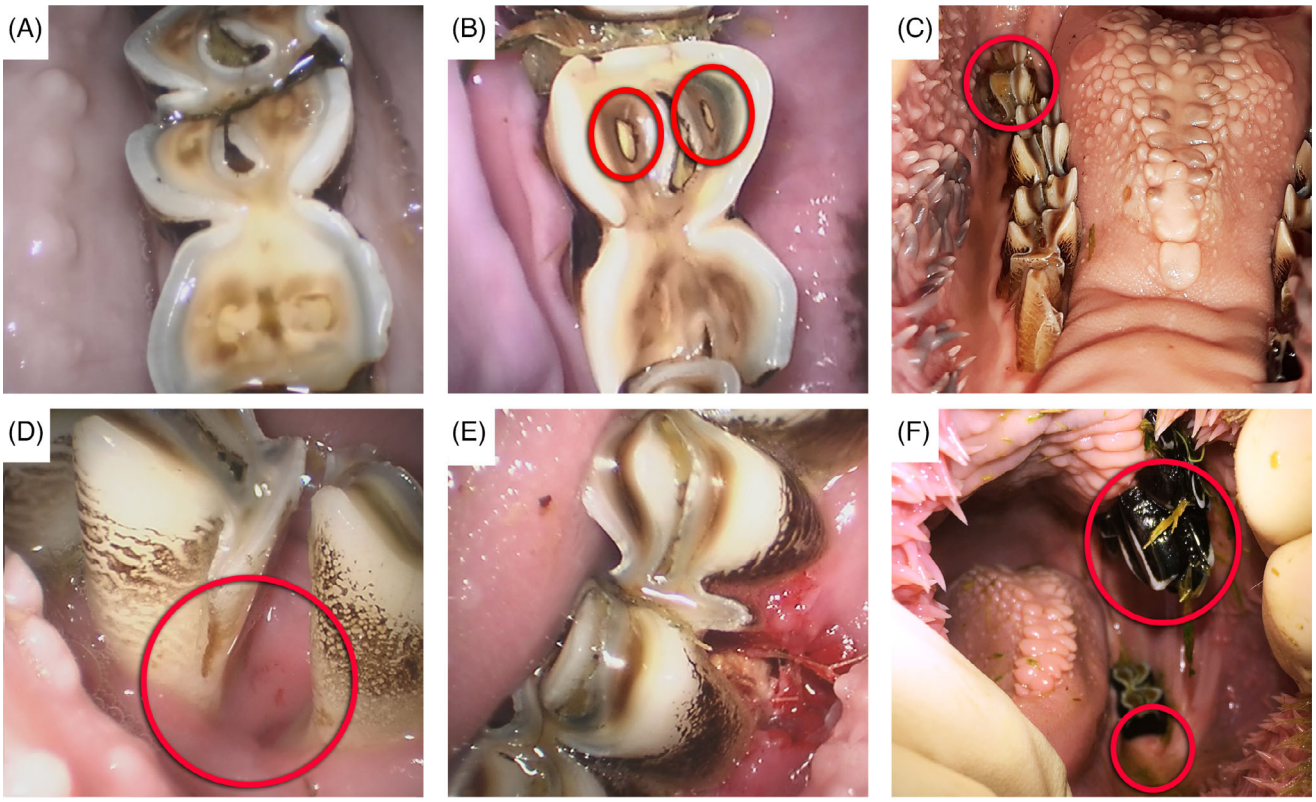

FIGURE 3 Lesions noted at the level of the cheek teeth. A, Worn tooth Triadan 309, mesial part in the senile excavation stage. B, Pulpar exposure at the level of the 2 distal pulp channels Triadan 309. Mesial part of Triadan 309 is worn. Diastema with food entrapment between element 309 and 310. C, Malpositioned Triadan 411. D, Diastema between element 808 and 409 after the removal of food, interproximal gum retraction is visible. E, Interproximal gum retraction combined with deep periodontal food pocketing and the presence of purulent material between element 708 and 309. Lingual chip fracture distal part of element 708. F, Missing Triadan 309 and Triadan 310. Super-eruption Triadan 209

3.3 | Prevalence of dental disorders at the animal level

The overall prevalence of dental disorders was 82.0% (187/228). Most pathology was encountered at the level of the cheek teeth (74.6%), whereas incisor and canine disorders were found in 41.7 and 3.9% of the animals, respectively.

Incisor disorders were identified in 95/228 animals (41.7%). These included diastemata (36/95; 15.8%), occlusal pulp exposure (25/95; 11.0%), malpositioned incisor teeth (23/95; 10.1%), and wear abnormalities (WA) (21/95; 9.2%). Less frequently encountered pathology included mandibular overbite (8/95; 3.5%), PD (8/95; 3.5%), and crown fracture (6/95; 2.6%). Persisting deciduous incisors and mandibular underbite each were found only in 2 animals, respectively. Missing incisors and peripheral cemental caries each were encountered only in 1 animal. Different incisor teeth disorders are illustrated in Figure 2.

Canine disorders were recorded in 9/228 (3.9%) animals. These included calculus in 3/228 animals (1.3%). Occlusal pulp exposure, PD, and dental-related soft tissue trauma attributable to the canines each were found in 2/228 (0.9%) animals, respectively. Uncomplicated crown fracture, bilateral malpositioning, and overgrowth of the canines each were found in 1 animal (0.4%). The location of the different canine and aforementioned incisor teeth disorders is described in Table 2.

Cheek teeth disorders were diagnosed in 169/228 (74.6%) animals. Generally, the most frequently encountered disorders included diastemata (97/228; 43.1%), WA (89/228; 39.6%), PD (75/228; 33.3%), and malpositioned teeth (44/228; 19.6%). Occlusal pulp exposure (23/228; 10.2%), persisting deciduous teeth (22/228; 9.6%), crown fractures (21/228; 9.2%), and missing teeth (8/228; 3.6%) were encountered less frequently. Infundibular caries (2/228) and supernumerary teeth (1/228) only were found occasionally. Oral soft tissue lesions were apparent in 4.8% (11/228) of alpacas. In 6 animals, no clear cause could be identified. In the other 5 animals (2.2%), lesions could be attributed to dental disorders and were classified as dental-related soft tissue trauma. Buccal lesions were found in 2 cases of increased molar mobility caused by advanced PD. Persisting deciduous teeth caused buccal lesions in 2 other cases. Gingival lesions were found in 1 animal caudal to the incisors in the mandibular arcade and were caused by overgrown maxillary canines. Remarkably, none of the oral soft tissue lesions could be attributed to the presence of enamel overgrowth. Different cheek teeth lesions are illustrated in Figure 3.

TABLE 3 Prevalence (%) and number (n) of alpacas affected by cheek teeth dental disorders stratified by age-group

Dental disorders	0-3 y (46)	>3-6 y (103)	>6-9 y (41)	>9-12 y (22)	>12-17 y (13)	Total (225)	*P* value
Diastemata	23.9%^{abc} (11)	36.1%^{de} (35)	51.2%^{afg} (21)	86.4%^{bdf} (19)	84.6%^{ceg} (11)	43.1% (97)	<.001
Wear abnormalities	26.1%^{abc} (12)	26.2%^{def} (27)	51.2%^{adg} (21)	86.4%^{beg} (19)	76.9%^{cf} (10)	39.6% (89)	<.001
Worn teeth	15.2%^{ab} (7)	13.6%^{cde} (14)	31.7%^{cfg} (13)	59.1%^{adf} (13)	76.9%^{beg} (10)	25% (57)	<.001
Shear mouth	0%	0%	2.4% (1)	4.5% (1)	7.7% (1)	1.3% (3)	.95
Wave mouth	0%	1% (1)	0%	0%	7.7% (1)	0.9% (2)	.70
Step mouth	0%	1% (1)	4.9% (2)	4.5% (1)	15.4% (2)	2.7% (6)	.41
Enamel overgrowths	0%	0%	4.9% (2)	9.1% (2)	0%	1.8% (4)	.99
Focal overgrowths	10.9% (5)	4.9% (5)	12.2% (5)	13.6% (3)	7.7% (1)	8.4% (19)	.50
Accentuated transverse ridges	0%	6.8%^{a} (7)	9.8%^{b} (4)	45.5%^{ab} (10)	23.1% (3)	10.5% (24)	<.001
Periodontal disease	15.2%^{abc} (7)	27.2%^{d} (28)	39.0%^{a} (16)	68.2%^{bd} (15)	53.8%^{c} (7)	32.0% (73)	.002
Mild gingivitis	4.3% (2)	6.8% (7)	4.9% (2)	9.1% (2)	7.7% (1)	6.2% (14)	.94
Interproximal gum retraction	10.9%^{abc} (5)	22.3%^{de} (23)	36.6%^{a} (15)	63.6%^{bd} (14)	53.8%^{ce} (7)	28.4% (64)	<.001
Presence of purulent material	4.3% (2)	4.9% (5)	4.9% (2)	13.6% (3)	0%	5.3% (12)	.61
Increased mobility	2.2% (1)	^{b}2.9% (3)	9.8% (4)	22.7% (5)	7.7% (1)	6.2% (14)	.43
Malpositioned teeth	4.3%^{ab} (2)	26.2%^{a} (27)	17.1% (7)	22.7%^{b} (5)	23.1% (3)	19.6% (44)	.11
Laterally malpositioned teeth	4.3% (2)	14.6% (15)	4.9% (2)	0%	15.4% (2)	9.3% (21)	.52
Medially malpositioned teeth	0%	13.7% (13)	12.2% (5)	22.7% (5)	15.4% (2)	11.1% (25)	.70
Occlusal exposure	2.2%^{ab} (1)	4.9%^{cd} (5)	9.8%^{ef} (4)	31.8%^{ace} (7)	46.2%^{bdf} (6)	10.2% (23)	.03
Persisting deciduous teeth	0%	14.6% (15)	12.2% (5)	9.1% (2)	0%	9.6% (22)	.97
Tooth fracture	6.5% (3)	5.8%^{a} (6)	14.6% (6)	13.6% (3)	23.1%^{a} (3)	9.2% (21)	.19
Focal gingival recession	2.2% (1)	3.9% (4)	4.9% (2)	4.5% (1)	7.7% (1)	4.0% (9)	.92
Missing teeth	0%	1%^{a} (1)	7.3% (3)	4.5% (1)	23.1%^{a} (3)	3.6% (8)	.07
Infundibular cariës	0%	0%	4.9% (2)	0%	0%	0.9% (2)	-
Supernumerary teeth	0%	0%	2.4% (1)	0%	0%	0.4% (1)	-

Notes: The association between age-group and specific cheek teeth disorders is reported (*P* value). Variables (a-g) with the same superscript in the same row are statistically significantly different at $P < .05$.

TABLE 4 Prevalence (%) and number of affected animals (n) of specific cheek teeth disorders with their mandibular/maxillar distribution

Cheek teeth disorders	Prevalence maxilla	Triadan position	Prevalence mandibula	Triadan position
Persisting deciduous teeth	8.0% (18)	07 (1), 08 (19)	2.2% (5)	07 (1), 08 (4)
Diastema	12.7% (29)	07-08 (1), 08-09 (10), 09-10 (19), 10-11 (20)	39.0% (89)	07-08 (8), 08-09 (30), 09-10 (68), 10-11 (53)
Periodontal disease	14.9% (34)	07 (1), 08 (1), 09 (2), 10 (1), diffuse[a] (1) 08-09 (9), 09-10 (19), 10-11 (24)	26.3% (60)	07 (2), 08 (2), 09 (2), 10 (1), 11 (1), diffuse[a] (1) 08-09 (11), 09-10 (35), 10-11 (38)
Mild gingivitis	2.7% (6)	07-08 (1), 08-09 (4), 09-10 (1), diffuse[a] (1)	4.0% (9)	08-09 (3), 09-10 (5), diffuse[a] (1)
Interproximal gingival retraction	12.4% (28)	08-09 (4), 09-10 (19), 10-11 (24)	23.1% (52)	07-08 (1), 08-09 (8), 09-10 (31), 10-11 (42)
Presence of purulent material	0.8% (2)	10 (2)	4.4% (10)	08-09 (1), 09-10 (2), 10-11 (3), 08 (3), 11 (1)
Increased mobility	2.7% (6)	07 (1), 08 (1), 09 (4), 10 (2)	4.0% (9)	07 (2), 08 (3), 09 (4), 10 (2), 407 (2)
Occlusal pulpar exposure	5.8% (13)	08 (1), 09 (13), 10 (5), 11 (2)	6.2% (14)	08 (1), 09 (9), 10 (7), 11 (4)
Missing teeth	1.3% (3)	07 (1), 08 (2), 10 (2), 11 (2)	3.1% (7)	08 (7), 09 (6), 10 (1), 11 (1)
Laterally malpositioned teeth	4.9% (11)	08 (1), 09 (4), 10 (10), 11 (9)	4.9% (11)	08 (3), 11 (12)
Medially malpositioned teeth	9.3% (21)	07 (18), 08 (7), 09 (7), 10 (1)	1.8% (4)	09 (1), 10 (4), 11 (1)
Wear abnormalities	14.9% (34)	07 (9), 08 (4), 09 (27), 10 (11), 11 (5), diffuse (2)	28.5% (65)	08 (28), 09 (75), 10 (5), 11 (6), 12 (2), diffuse (2)
Worn teeth	4.0% (9)	07 (1), 08 (1), 09 (11)	24.0% (54)	07 (1), 08 (34), 09 (67), 10 (4), 11 (1)
Wave mouth	0.8% (2)	-	0.4% (1)	-
Step mouth	2.2% (5)	09 (4), 10 (2)	0.4% (1)	09 (1), 10 (1)
Enamel overgrowths	1.3% (3)	08 (2), 10 (2), diffuse (2)	1.3% (3)	09 (1), diffuse (2)
Focal overgrowths	3.6% (8)	07 (9), 08 (2), 11 (1)	4.9% (11)	07 (1), 08 (7), 09 (1), 11 (2), 12 (2)
Accentuated transverse ridges	7.6% (17)	09 (10), 10 (7), 11 (5)	4.0% (9)	09 (5), 10 (3), 11 (3)
Tooth fracture	2.2% (5)	08 (1), 09 (3), 11 (1)	7.1% (16)	08 (5), 09 (4), 10 (6), 11 (5)
Focal gingival recession	1.3% (3)	09 (2), 10 (1)	2.7% (6)	08 (2), 09 (1), 10 (2), 11 (1)
Infundibular caries	0%	-	0.8% (2)	09 (2)
Supernumerary teeth	0%	-	0.4% (1)	12 (2)

Note: Location of each abnormality is reported on a tooth/interproximal level.

[a]Periodontal disease/mild gingivitis over the entire length of the maxillary/mandibular arcade.

Significant associations were found between age group and cheek teeth disorders, diastemata, PD, interproximal gum retraction, increased mobility, occlusal pulp exposure, missing teeth, malpositioned teeth, medially malpositioned teeth, WA, worn teeth, step mouth, enamel overgrowth, and accentuated transverse ridges (Table 3). Over the different age categories, prevalence of cheek teeth disorders ranged from 50.0% in the youngest age group to 100% in the oldest 2 age groups.

3.4 | Persisting deciduous teeth

In 3 animals, 2 concurrent persisting deciduous teeth were noted (508 and 608). Only 1 persisting element was identified in 19 other animals. Location of the different persistent deciduous teeth and other specific cheek teeth disorders were recorded (Table 4).

3.5 | Diastemata and PD

In animals diagnosed with ≥1 diastemata, the number of diastemata per animal ranged from 1 to 7 with a mean of 2 ± 1. The majority of diastemata showed food impaction. Concurrent PD was seen in 60/97 (61.9%) cases. Animals ranging from 9 to 12 years old more frequently were diagnosed with PD than were younger animals (Table 3). Periodontal disease had a higher prevalence at the level of the mandible (61/75; 81.3%; Table 4). In both maxillary and mandibular arcades, PD was observed more frequently between the caudal teeth.

3.6 | Wear abnormalities

Accentuated transverse ridges were found in 24/228 (10.5%) animals. They were located directly opposing a diastema in 14/24 (58.3%) cases. Furthermore, accentuated transverse ridges more frequently were observed at the mesial aspect (n = 17, 70.8%) compared to the distal part of the affected tooth (n = 8, 33.3%). Bilateral supernumerary 312 and 412 teeth were found in 1 animal. Their distal occlusal surface was severely overgrown.

3.7 | Tooth fractures

Tooth fractures were more commonly found at the level of the mandibular cheek teeth (19/23) as compared to the maxillary cheek teeth (4/23). One tooth (308) was fractured in a sagittal plane. Eleven of

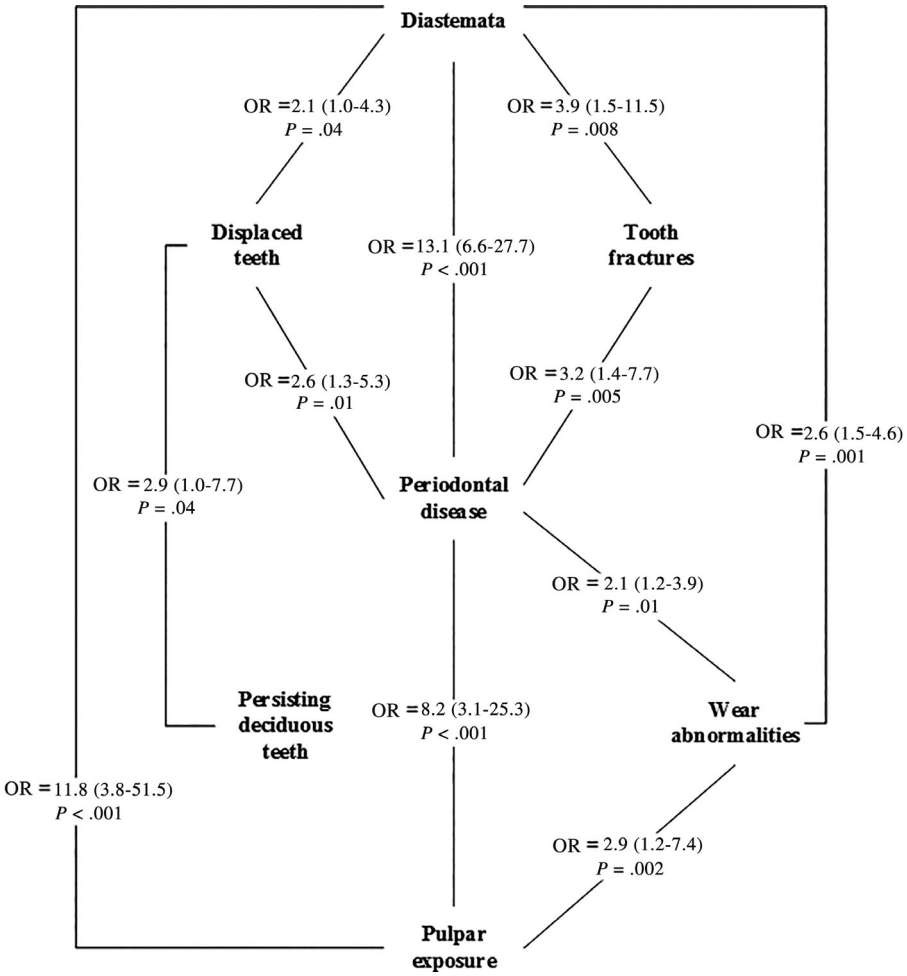

FIGURE 4 Associations between the different detected dental disorders in alpacas. Odds ratios and *P* values of the different relations are depicted. The 95% confidence interval of the odds ratios is included between brackets

21 fractures could be categorized as slab fractures involving ≥1 dental stars. Nine simple chip fractures only involved peripheral enamel ridges (and sometimes adjacent primary dentin).

3.8 | Associations between dental disorders

Associations between different dental disorders are illustrated in Figure 4. Strong relationships were noted between the presence of diastemata, PD, and occlusal pulpar exposure. Additionally, WA demonstrated an important association with the presence of exposure of the pulp cavity and the presence of diastemata.

4 | DISCUSSION

Our aim was to determine the prevalence of specific dental disorders in alpacas and to study possible relationships. Furthermore, farm-specific differences in prevalence of dental disorders were of interest. Our study provides the first estimates of the prevalence of different dental disorders in alpacas, excluding apical infections. The latter diagnosis only can be made based on a thorough clinical and oral examination combined with additional diagnostic techniques, such as radiography or computed tomography.[1] The mean age of alpacas examined in our study was 5.6 years (range, 1-17 years), which we believe is a good representation of the age distribution in the current alpaca population found in Belgium and the Netherlands. The high prevalence of dental disorders (82%), more specifically cheek teeth disorders (74.6%), found in our study is in accordance with reports in other herbivorous species, such as Old World Camelids, equids, small ruminants, and cattle.[7,8,10-18] The prevalence of incisor disorders in our alpaca population was relatively low in comparison with cheek teeth disorders. Similar results have been obtained for incisor disorders in sheep in Slovenia,[8] whereas in young beef cattle, a necropsy study found a relatively higher prevalence of incisor disorders in comparison with cheek teeth disorders.[9] Unlike the high prevalence of incisor PD in sheep, only 3.5% of the alpacas in our study showed signs of PD at the level of their incisors.[8,27,28] However, a cautious approach is necessary when comparing the prevalence of dental disorders among animals, species, and studies given the differences in age, study design and definitions used to describe specific pathologies.

With increasing age, cheek teeth disorders were more prevalent, as has been observed in other species.[12-15] Significant differences were found between age group A (0-3 years) and age groups B (3.1-6 years) and C (6.1-9 years). No significant differences could be detected for the other age groups. The smaller sample sizes in the latter groups could explain the lack of statistically significant evidence. A high prevalence of cheek teeth disorders was noted even in young age groups, with WA commonly diagnosed and ranging from 26.1% in young animals to 86.4% in older animals. Similar results have been found in donkeys.[12] In young alpacas, only worn teeth and focal overgrowths were found. These disorders have been perceived predominantly in the deciduous dentition, before shedding, after a period of continued eruption and abrasion of the occlusal surface. The high prevalence of WA in the older age group was caused by the high prevalence of worn teeth in this group, most commonly expected to exist in older animals. Contrary to the results obtained in donkeys, where worn teeth are found mostly at the Triadan "10" and "11" position in the maxillary arcade, worn teeth in alpacas predominantly were present in the mandibular arcade, more specifically at positions "08" and "09."[12] This difference can be partly attributed to the fact that the "09" position is the first of the molars in eruption and therefore already used for grinding at a relatively young age. Furthermore, our results suggest that the largest masticatory forces possibly could be centered at the "09" position. However, this hypothesis warrants further research to measure masticatory forces and make a definite conclusion. Additionally, the difference in wear pattern in comparison to donkeys also can be partly attributed to the prominent curve of Spee in donkeys, which does not exist as such in alpacas.

Our study found a high prevalence of diastemata in the alpaca population. Strong variation in the prevalence of diastemata is found in other species, especially in equids. Given the variety of descriptions and methodology used in the current literature, the utilized definition for diastemata in different studies should be taken into account when comparing results. Furthermore, the age of included animals should be taken into account when comparing results.[12,15,16,19,20,29-32] A relatively high prevalence of diastemata already exists in the younger age groups A (0-3 years) and B (>3-6 years), with a reported prevalence of 23.9 and 36.1%, respectively. This finding suggests diastemata to be in part a congenital problem in the current alpaca population. The significantly higher prevalence of diastemata in the older age groups is attributed more to the development of senile diastemata, as described in horses. They develop after continued eruption of teeth and a decreasing crown diameter toward the apices, resulting in decreased surface area at the level of the occlusal surface.[33] The strong association between the prevalence of diastemata and PD also has been noted in other species.[19,20,30] Resultant food impaction and fermentation initiates an inflammatory process in the periodontal supporting structures. Deep periodontal pocketing can result in apical infection[34] and pulpitis with occlusal pulp exposure in chronic cases because of further tooth wear, indicating nonvital pulp tissue as described in horses.[35]

In contrast to the findings in equids, only a low prevalence (2.2%, 5/228) of dental-related soft tissue trauma was present in our alpaca population. Additionally, none of the animals that exhibited soft tissue trauma in the mouth showed concurrent enamel overgrowth as commonly found in equids.[36] The primary causes of dental-related soft tissue trauma in our study were persisting deciduous teeth and increased tooth mobility because of advanced PD. Dental examinations performed on a regular basis can aid in early detection and prevention of dental disorders responsible for painful oral lesions. Routine floating of sharp enamel points as advised and performed in equine dentistry has not been encouraged in alpacas.[1] However, it should be noted in specific situations, certain irregularities in the dentition can cause lesions in the oral mucosa, which can benefit from an appropriate corrective procedures.

Within herd prevalence of different specific dental disorders varied among the examined farms, ranging from 0 to 100%. This variation

can be explained by differences in the number of animals per farm (range, 1-28 animals) as well as age differences among farms, the latter ranging from 2.5 ± 0.5 to 13.4 ± 0.4 years old, with a mean age of 5.60 ± 3.17 years within farms. Further research focusing on management, housing and feeding practices is warranted to gain more insight into their role as risk factors for dental pathology in alpacas.

Only a few alpacas in our study had previously undergone dental examinations. This finding is in contrast with the current situation in horses. Routine dental prophylaxis has come to the attention of owners over the past few years in the latter species.[37] Our study shows that alpacas also could benefit from prophylactic oral examinations to assess dental health and detect dental disorders at an early stage. However, a thorough oral examination only can be carried out in sedated animals. In equids, this examination can be performed using mild sedation with the animal remaining standing. In alpacas, the protocol used for this examination should provide deep sedation, which will cause most animals to become recumbent. The sedation protocol used in our study was sufficient to allow thorough examination, and resulted in a rapid and smooth recovery with most animals standing within 15 minutes after finishing the examination. The same thorough approach for the oral examination should be used as already described in equids to allow identification of the different pathologies, using a speculum, light source, and dental mirror or rigid portable endoscope or both.[22,25] After diagnosis, several treatment options currently are available in alpacas including correction of abnormalities of wear, cleaning diastemata and periodontal pockets of impacted food, occluding diastemata, and extraction of persisting deciduous teeth, fractured teeth, apically infected teeth or teeth involved in severe PD.[1,2,5,6]

Ours is the largest prevalence study on dental disorders in alpacas currently available. For practical reasons, our study was prone to selection bias. Given the absence of a national registration system for camelids in both countries, farms had to be selected from volunteering members of the Alpaca Association Benelux. Some owners might have volunteered because they already suspected some of their animals to have dental pathology. Despite our study limitation, we believe that we screened a sufficient variety of farms and animals for our results to be of scientific value. Nevertheless, differences between the current results and those of comparable studies conducted in another geographical region might exist.

In conclusion, dental disorders appear highly prevalent in the studied Western European alpaca population, especially at the level of the cheek teeth and in older animals. Important associations were detected for different dental disorders. Our findings highlight the importance of routine dental examinations in sedated alpacas to allow early detection of dental disorders and thereby improve general welfare. Additionally, farm-specific differences in prevalence of different dental disorders were found. Further research is warranted to identify possible risk factors contributing to the development of dental disease in alpacas.

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CONFLICT OF INTEREST DECLARATION

A call for volunteering alpaca farms was spread through the Alpaca Association Benelux (AAB). One of the coauthors (T. Flahou) is member of the AAB and participated in this study with animals present at his alpaca farm. The AAB played no role in the final selection of participating farms neither in the collection, analysis and interpretation of data, nor in the decision to submit the manuscript for publication. B. Pardon acted as an unpaid consultant for the AAB. None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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