Disease in wildlife or exotic species

Oral, Maxillofacial and Dental Diseases in Captive Cheetahs (Acinonyx jubatus)

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Summary

Descriptions of several oral, maxillofacial and dental conditions/diseases exist for a variety of captive large felids, but little is reported on the pathology of free roaming large felids. Apart from focal palatine erosions (FPEs) as initially described by Fitch and Fagan (1982) and some reference to absent incisor teeth, few data exist on diseases affecting the oral, maxillofacial and dental structures of cheetahs (*Acinonyx jubatus*), regardless of their captivity status. This study reports 18 different conditions affecting the teeth, bone and oral cavity soft tissue of cheetahs, based on initial assessment of 256 animals over 11 years (2002–2012) in South Africa and Namibia. This report excludes oral tumours or FPEs, but includes several acquired and developmental condi-tions never described before.

Keywords: cheetah; maxillofacial; oral cavity; teeth

Introduction

The cheetah (*Acinonyx jubatus*) is classified as a large felid that shares some characteristics with the Canidae (Caro, 1994). A variety of oral, maxillofacial and dental conditions/diseases (OMFD's) occurs in captive felids, mainly lions, tigers, leopards and snow leopards (Heuschele, 1959; Willis, 1983; Cook and Stoller, 1986; Beebe and Hulland, 1988; van Foreest and Roeters, 1997; van Foreest *et al.*, 1999; Sundberg *et al.*, 2000; De Simoi, 2006; Barycka, 2007; Sykes *et al.*, 2007; Longley, 2011). Although these studies help to describe the pathology seen in these captive big cats, few such reports are currently available for free living big cats (Van Valkenburgh, 1988; Miles and Grigson, 1990; Van Valkenburgh and Hertel, 1993; Longley *et al.*, 2007).

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Apart from focal palatine erosions (FPEs), an oral condition described in cheetahs (Fitch *et al.*, 1982) and dealt with in a PhD thesis (Steenkamp, 2017), little information regarding other OMFD's exists for either captive or free living cheetahs (Miles and Grigson, 1990; Kertesz, 1993; Roux *et al.*, 2009; Brettschneider *et al.*, 2015).

The aim of the present study was to describe the OMFD's (excluding FPEs) seen in two groups of captive cheetahs originating from Namibia and South Africa. Improved knowledge on these conditions that occur in captive cheetahs, and its potential impact on these cats, will be valuable in captive management of this species.

Materials and Methods

Data were obtained from cheetahs examined from 2002 to 2012 at two captive facilities, the Ann van Dyk Cheetah Centre in South Africa and the AfriCat

Foundation in Namibia. The Ann van Dyk Cheetah Centre (DW), situated at de Wildt near Pretoria in South Africa (S 25° 40′ 25.1″ E 27° 55′ 25.4″), is a captive breeding facility, which includes a small number of wild caught cheetahs. The AfriCat Foundation, situated at Okonjima in Namibia (S 20° 51′ 59″ E 16° 38′ 22″) (AF), is a rescue sanctuary for trapped or injured wild cheetahs from Namibia without any captive breeding.

As part of the annual animal health assessments at these two facilities, the oral cavities of cheetahs were examined clinically according to predefined criteria (Table 1) and findings were recorded on a feline dental record sheet. Clinical evaluations were done utilising a calibrated periodontal probe and dental explorer. Dental radiography was unavailable in most cases and was therefore not used in this study. Any soft tissue pathology identified clinically was subject to biopsy and tissue was preserved in 10% neutral buffered formalin, processed routinely and embedded in paraffin wax. Sections (5 μm) were stained with haematoxylin and eosin (HE). Only the first examination data for each animal were used to compile the frequencies of the different conditions encountered. Frequency determinations for dental pathology were corrected for absent teeth. The OMFD's evaluated in this study included skeletal abnormalities (e.g. malocclusions because of jaw length discrepancies), dental conditions, as well as soft tissue pathology excluding soft tissue masses.

Table 1. Scoring system used in the oral evaluation of 256 cheetahs against thirteen parameters

Observation	Score	Criteria/Description
Sex	0	Unknown
	1	Male
	2	Female
	3	Male neutered or given contraception
	4	Female neutered or given contraception
Age	0	Unknown
	months	Age in months
Status	−5	Not recorded
	0	Wild caught <10 months
	1	Wild caught >10 months
	2	Captive bred
	3	Wild
Skull conformation	0	Normal
	1	Brachycephalic
	2	Mandibular prognathism
	3	Mandibular brachygnathism
Tooth presence	−5	Not Recorded
	0	Absent
	1	Present
	2	Root remnants with or without draining fistula (RR visible)
	3	Draining fistula (RR not visible)
Recession	−5	Not Recorded
	−1	Tooth absent
	mm	Distance from gingiva to enamel cemento-enamel junction
Tooth wear	−5	Not Recorded
	−1	Tooth absent
	0	No wear
	1	Wear facets present
	2	Wear pulp exposed
Tooth fractures	−5	Not Recorded
	−1	Tooth absent
	0	None
	1	Enamel chip fracture
	2	Uncomplicated crown fracture
	3	Complicated crown fracture
	4	Uncomplicated crown−root fracture
	5	Complicated crown−root fracture
	6	Loss of filling (previous RCT)
Tooth resorption (RL)	−5	Not Recorded
	−1	Tooth absent
	0	No resorption present
	1	Tooth resorption present
Periodontal pocket	−5	Not Recorded
	mm	Depth measured from gingival margin to deepest aspect of pocket
Furcation lesion	−5	Not Recorded
	0	None present
	1	Furcation area exposed, no bone loss
	2	Furcation area exposed, bone loss approximately 50% of alveolar bone
	3	Furcation area exposed, complete bone loss through-and-through defect
Incisor crowding	−5	Not Recorded
	0	Normal
	1	Incisors crowded
Tooth rotation	−5	Not Recorded
		Rotation of tooth (in degrees), approximated
Other		Any other pathology or anomalies were described

For the purpose of this study, periodontal disease was defined as any condition causing periodontal attachment loss, namely periodontal pockets > 3 mm, gingival recession and/or furcation lesions.

Statistical analyses, including hypothesis testing, were done using SAS software, Version 9.3 of the SAS System for Windows (SAS Institute, Cary, North Carolina, USA) and IBM SPSS Statistics for Windows, Version 23.0 (IBM Corporation, New York, New York, USA). Results were interpreted as significant when $P < 0.05$ and highly significant when $P < 0.01$.

Results

Data collected from 256 cheetahs, evaluated over 11 years at the two facilities, are included (Table 2). The seven wild-caught DW cheetahs are incorpo-rated in the DW totals. Box plots illustrate the age distributions (Fig. 1), while descriptive measures for specific tooth indices are summarized (Table 2). Kruskal—Wallis tests confirmed significant differences between at least two of the median ages (Table 3). Dunn's multiple comparison tests confirmed that the median ages of cheetahs differed significantly between the two facilities, but not be-tween sexes in the same facility (Table 3). Conse-quently, where applicable, age was included as a predictor in the statistical analyses with respect to pa-thology.

Skeletal Pathology

Incisor Crowding. Clinical crowding of the mandibular incisors (class I type malocclusion) occurred in both populations (Fig. 2). In the DW population, 27.6% (24/87) of males and 19.5% (15/77) of females had crowding of the incisor teeth, while 21.3% (10/47) of males and 13.5% (5/32) of females in the AF population had this problem. A maximum likelihood analysis of variance showed no difference in incisor crowding between the two facilities ($P = 0.2463$) or between the sexes at each facility ($P = 0.1359$).

Brachycephalic Skull Type. At DW, two siblings, one male (M366) and one female (F367), had a brachycephalic skull conformation as determined clinically by an extremely short nose (class III malocclusion)(Fig. 3).

Mandibular Prognathism. One male cheetah (M395) at DW had mandibular prognathism, seen as mandibular canines and incisor teeth classically positioned rostrally to the maxillary opponent teeth (class III type malocclusion) when in occlusion (Fig. 4).

Dental Pathology

Absent Teeth. A total of 7,127 teeth (92.79%), out of a potential 7,680 teeth (some teeth were absent from the jaw[s]), were evaluated. The teeth absent most

Table 2. Descriptive statistics of the number, age, absence and rotation of teeth in the 256 cheetahs evaluated

	AfriCat		De Wildt	
	Male	Female	Male	Female
Number	47	45	88	76
Age (months)				
Mean	65.52	56.64	34.7	40.11
Standard deviation	41.35	37.17	23.85	29.27
First quartile (Q1)	30	24	15	15
Median	66	55.5	27	28
Third quartile (Q3)	96	84	47.5	50
Absent teeth				
101	19.1% (9/47)	28.9% (13/45)	3.4% (3/88)	3.9% (3/76)
102		22.2% (10/45)	3.4% (3/88)	
106				5.3% (4/76)
201	21.3% (10/47)	22.2% (10/45)	3.4% (3/88)	
202	19.1% (9/47)			
206			3.4% (3/88)	5.3% (4/76)
Rotation of tooth				
106	14.9% (7/47)	11.1% (5/45)	19.3% (17/88)	22.4% (17/76)
206	6.4% (3/47)	8.9% (4/45)	15.9% (14/88)	19.7% (15/76)
Bilateral	6.4% (3/47)	8.9% (4/45)	13.6% (12/88)	18.4% (14/76)

The three most commonly absent teeth are included in this table (DW male represented by four teeth as they all had the same frequency of three out of 88).

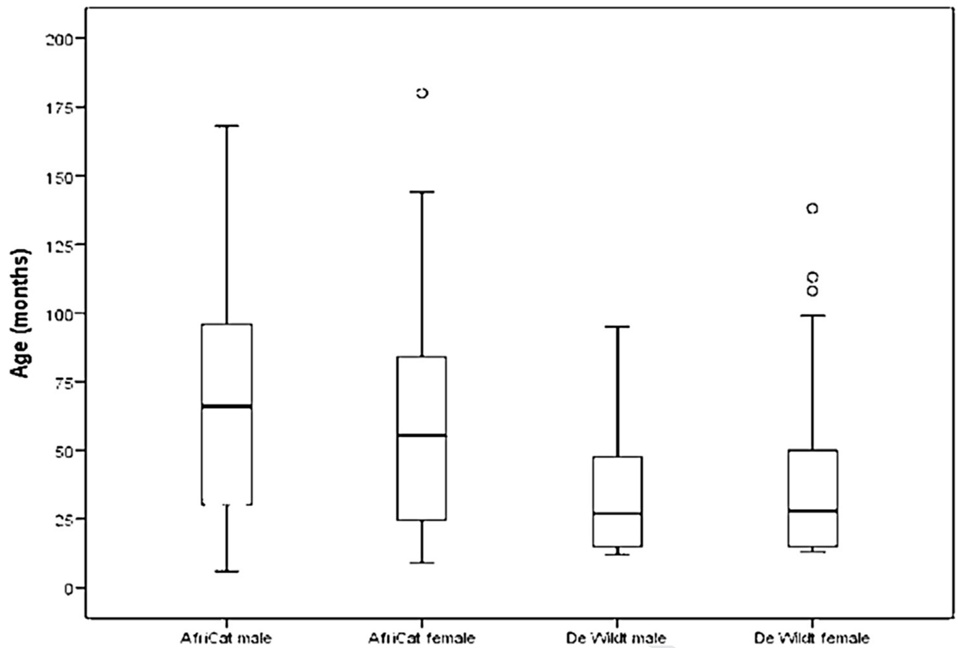

Fig. 1. Box plots displaying the age distributions (in months) of the male and female cheetahs in each facility.

frequently in both sexes at both facilities were the first two maxillary incisors (Fig. 2) followed by the 2nd premolar teeth at the DW facility only (Table 2). In total 67 (33 male, 34 female) out of 256 (26.17%) cheetahs had one or more teeth absent during the 1st visit. These comprised 21 (10 male, 11 female) out of 164 (12.8%) cheetahs from DW and 46 (23 males, 23 females) out of 92 (48.91%) cheetahs from AF.

Tooth Rotation. Rotation of a tooth, defined as movement of a tooth around its long axis, at both facilities and in both sexes was limited to the maxillary 2nd premolars (Fig. 5). The right side of the upper jaw was more commonly affected than the left, with bilaterally rotated teeth encountered frequently (Table 2).

Talon-like Cusps. In all 13 cheetahs below the age of 20 months, from both facilities, the morphology of all the maxillary incisors, and especially the 3rd incisor (Fig. 6), closely resembled the morphology of a talon cusp. This manifested as an accessory, curved cusp present mostly on the palatal aspect of these teeth.

Table 3
***P* values for Kruskal–Wallis tests and Dunn's multiple comparison tests for the medians of age of cheetahs compared between facilities as well as between sexes**

Comparison	Test	Age
DW male versus DW female versus AF male versus AF female	Kruskal–Wallis	<0.0001
DW male versus DW female	Dunn	1.000*
DW male versus AF female	Dunn	0.004
DW male versus AF male	Dunn	<0.0001
DW female versus AF female	Dunn	0.049
DW female versus AF male	Dunn	0.002
AF female versus AF male	Dunn	1.000*

*Comparisons not significant.

Fig. 2. A female cheetah with incisor crowding (class I malocclusion), enamel defects of the canines and central maxillary incisors as well as an absent right 3rd mandibular incisor tooth.

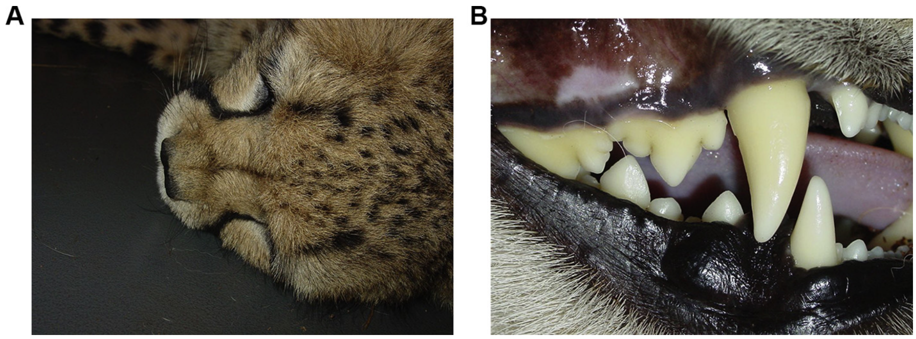

Fig. 3. (A) A Female cheetah with a brachycephalic head (class III malocclusion). (B) Because of the shortened maxilla there is no diastema between the canine and 3rd maxillary premolar tooth where the 2nd premolar should normally be situated.

Tooth Resorption. External tooth resorption was identified only once, affecting the right maxillary canine of a DW female. No intra-oral radiography was available in order to quantify the extent of tooth resorption in this cheetah or evaluate the overall incidence of internal tooth resorption.

Tooth Fractures. Complicated crown fractures, defined as a fracture extending through enamel, dentine and pulp, were the most commonly encountered fracture pattern seen at both facilities. The frequencies and types of tooth fractures as per facility, sex and jaw position are shown in Figs. 7 and 8. In this study, 189 (73.8%) cheetahs had at least one fractured tooth present at first visit. Pearson's correlation showed highly significant correlation between the number of tooth fractures and age ($r = 0.504$, $P < 0.0001$).

Fig. 4. A male cheetah with mandibular prognathism (class III malocclusion). The mandibular incisor is situated rostral to the mandibular incisors, the mandibular canine is rostral to the area where it should occlude and the mandibular 3rd premolar tooth is occluding on the palatal aspect of the maxillary canine.

Persistent deciduous teeth. Two unrelated female cheetahs at DW had persistent deciduous teeth (a right maxillary canine in 15-month-old F523 and right mandibular 3rd premolar in 13-month-old F539). One 12-month-old male cheetah with a persistent deciduous left maxillary canine was found at AF (Fig. 9).

Supernumerary Teeth. One male cheetah at DW had a supernumerary right mandibular 4th premolar tooth (extra tooth 408) and one male at AF had a supernumerary right maxillary 2nd premolar tooth (extra tooth 106) (Fig. 10).

Impacted Teeth. One male cheetah at AF had an abnormal, partially erupted, maxillary right canine tooth (Fig. 11A). Histologically, the associated dental follicle was recognisable as a myxoid connective tissue capsule associated with the partially erupted crown with some inactive appearing odontogenic epithelial islands distributed throughout the soft tissue. The tooth had normal coronal anatomy, but ended in two apices (Fig. 11B). No periodontal ligament space

Fig. 5. The right 2nd maxillary premolar tooth in this cheetah is approximately 45 rotated. The arrow indicates the direc-tion of rotation around its long axis.

Fig. 6. A young female cheetah showing the palatal protuberance of the left maxillary 3rd incisor tooth, commonly referred to as a 'talon cusp' in man. All of the other maxillary incisors also have a prominent cingulum reminiscent of a double semi-talon as described in man.

was found between the adjacent alveolar bone and dental cementum. The tooth root was ankylosed to the alveolar bone, most probably the reason for the cessation of eruption and impaction.

Periodontal Disease. Logistic regression analysis indicated no difference in the frequency of periodontal disease between the sexes ($P = 0.1851$), although there was a significant difference in the frequencies of occurrence between the two facilities ($P = 0.0138$). AF cheetahs demonstrated a 2.514 times higher risk for periodontal disease than those at DW (95% Wald confidence interval: 1.207, 5.233). Periodontal disease furthermore significantly increased with age ($P < 0.0001$), with the odds of a cheetah having periodontal disease being 1.056 times higher for each additional month in age (95% Wald confidence interval: 1.040, 1.072). Gingival recession was the most common form of periodontal disease encountered (Fig. 10A). Using logistic regression, the frequency of recession showed no significant difference between the sexes ($P = 0.1304$), but a significant difference was found between the two facilities ($P = 0.0284$), while age was also a significant predictor ($P < 0.0001$). Specifically, the odds of an AF cheetah exhibiting recession were 2.288 times greater than for a DW cheetah (95% Wald confidence interval: 1.091, 4.798). The odds of a cheetah having gingival recession was 1.057 times higher for each additional month in age (95% Wald confidence interval: 1.041, 1.073).

Tooth Wear. Logistic regression modelling showed that tooth wear (i.e. loss of enamel and dentine) was significantly more common in AF cheetahs compared with the DW animals ($P < 0.0001$) with an estimated odds ratio of 6.965 (95% Wald confidence interval: 2.977, 16.296). There was no difference between the sexes ($P = 0.7088$). At AF, 94 teeth (57 in males and 37 in females) were worn with pulp exposure compared with only 27 teeth (four in males and 23 in females) at DW. Tooth wear also significantly increased with age ($P < 0.0001$). The odds of a cheetah having tooth wear was generally 1.04 times higher for each additional month in age (95% Wald confidence interval: 1.024, 1.055). Tooth wear at AF was generalized (Fig. 12A), while more specific wear of the maxillary 3rd incisors (103, 203), maxil-lary canines (104, 204), mandibular canines (304, 404) (Fig. 12B) and mandibular molars (309, 409) were seen at DW. At DW, six cheetahs also had labial surface wear with pulp exposure in both their maxillary and mandibular canines (Fig. 12C). Fig. 13 demonstrates the tooth wear frequencies and sex differences between the two facilities.

Enamel Defects. Enamel defects, defined here as focal or multifocal reduction in the clinical quantity or quality of the enamel, occurred in both populations (Fig. 2). Some 2.3% (2/87) of males and 3.9% (3/77) of females at DW were affected compared with 4.3% (2/47) of males and 2.7% (1/37) of females at AF.

Discoloured Teeth. Six canine teeth (one in each of two DW females, one in each of two AF males, and one in each of two AF females) appeared pink–grey in colour (Fig. 14).

Radicular Cyst. One male cheetah at DW (M420) had a draining sinus tract associated with the non-vital left mandibular canine tooth. On extraction, the periapical soft tissue was examined histologically, which confirmed the diagnosis of a radicular cyst. The cyst wall consisted of dense connective tissue lined focally by ulcerated, proliferating, stratified squamous epithelium with mixed inflammatory cells distributed throughout the connective tissue.

Soft Tissue Pathology

Palatal Ulcers. Non-specific ulcers of the hard palate, not compatible with focal palatine erosion (FPE),

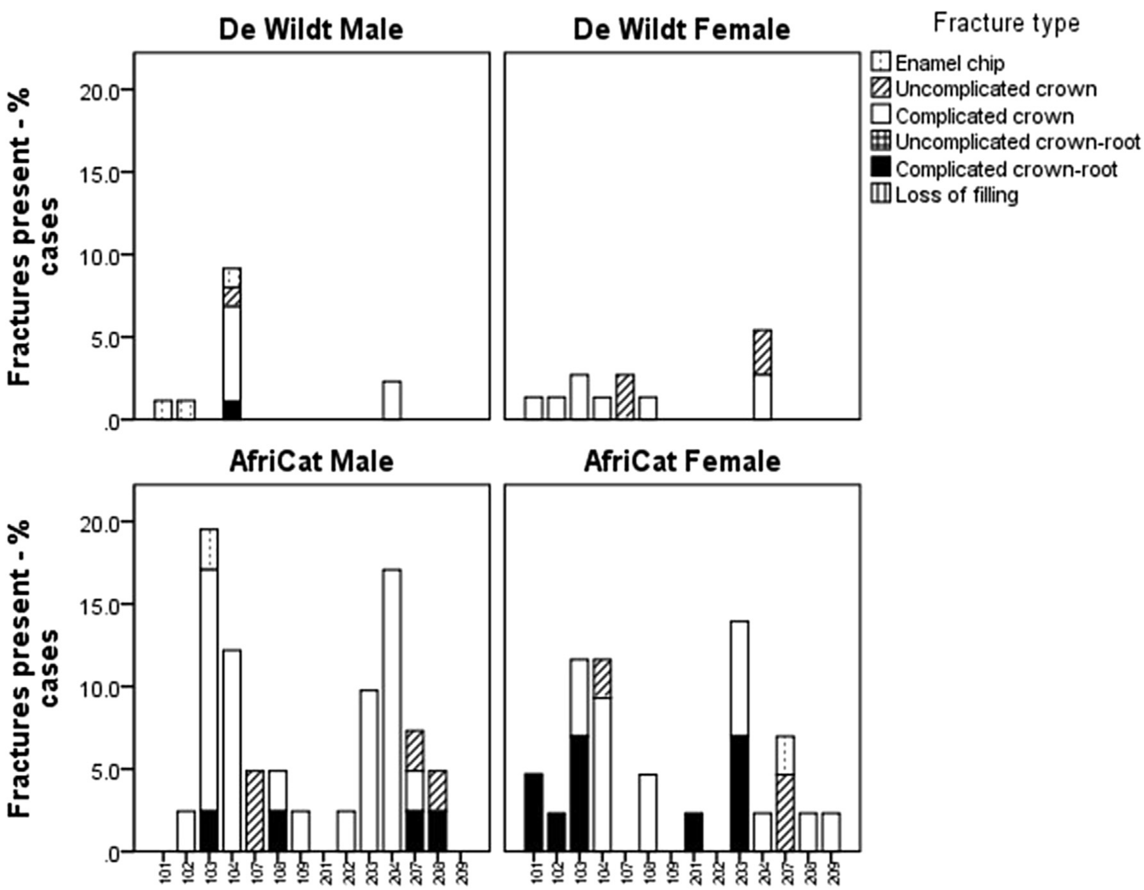

Fig. 7. The frequency and type of tooth fracture present in the maxillae of cheetahs by sex and by facility. The teeth are numbered using the modified Triadan system (Floyd, 1991).

were found in two DW males (2.3%), one DW female (1.3%) and two AF males (4.3%). Histological exam-ination excluded neoplasia and confirmed the chronic nature of the non-specific ulceration through the pres-ence of fibrosis and chronic inflammatory cell infiltra-tion of the ulcer bed.

Feline Papilloma Lesions. Exophytic, proliferative papillary lesions on the ventral tongue surface of AF cheetah resembling feline papilloma virus lesions were present in 4.3% (2/47) males and 8.1% (3/37) females (Fig. 15). Histologically koilocyte-like change, multinucleation of the epithelium as well as the focal presence of mitosoid bodies were reminiscent of a papilloma virus-associated lesion. These lesions were not seen in animals from DW. Molecular studies confirmed the lesions to be caused by a unique feline papilloma virus (FPV)(Brettschneider *et al.*, 2015).

Discussion

This study describes and compares the OMFD pathology in 256 cheetahs from two geographically different facilities (South Africa and Namibia) over 11 years of clinical examinations (2002–2012). Cheetahs at AF are wild caught animals, while those at DW are predominantly captive bred, facilitating the comparative study of OMFD's in these two populations. Eighteen types of non-neoplastic pathology were identified and, for descriptive purposes, categorized as skeletal, dental and soft tissue pathology.

Skeletal malocclusion as a result of jawbone abnormalities in man appears to be multifactorial in aetiology with both genetic and environmental factors contributing (Moreno Uribe and Miller, 2015). The present study is the first to report skeletal malocclusion in cheetahs.

Class I malocclusions (incisor crowding) were the most common abnormality in this category. A variety of genetic and non-genetic factors are considered in its aetiopathogenesis including abnormally narrow mandibles, the presence of persistent deciduous teeth, supernumerary teeth (Niemiec, 2010), trauma or the phenomenon of relative macrodontia (i.e. abnormally large teeth in a normal sized jaw or normal sized teeth in an abnormally small jaw; Moreno Uribe and

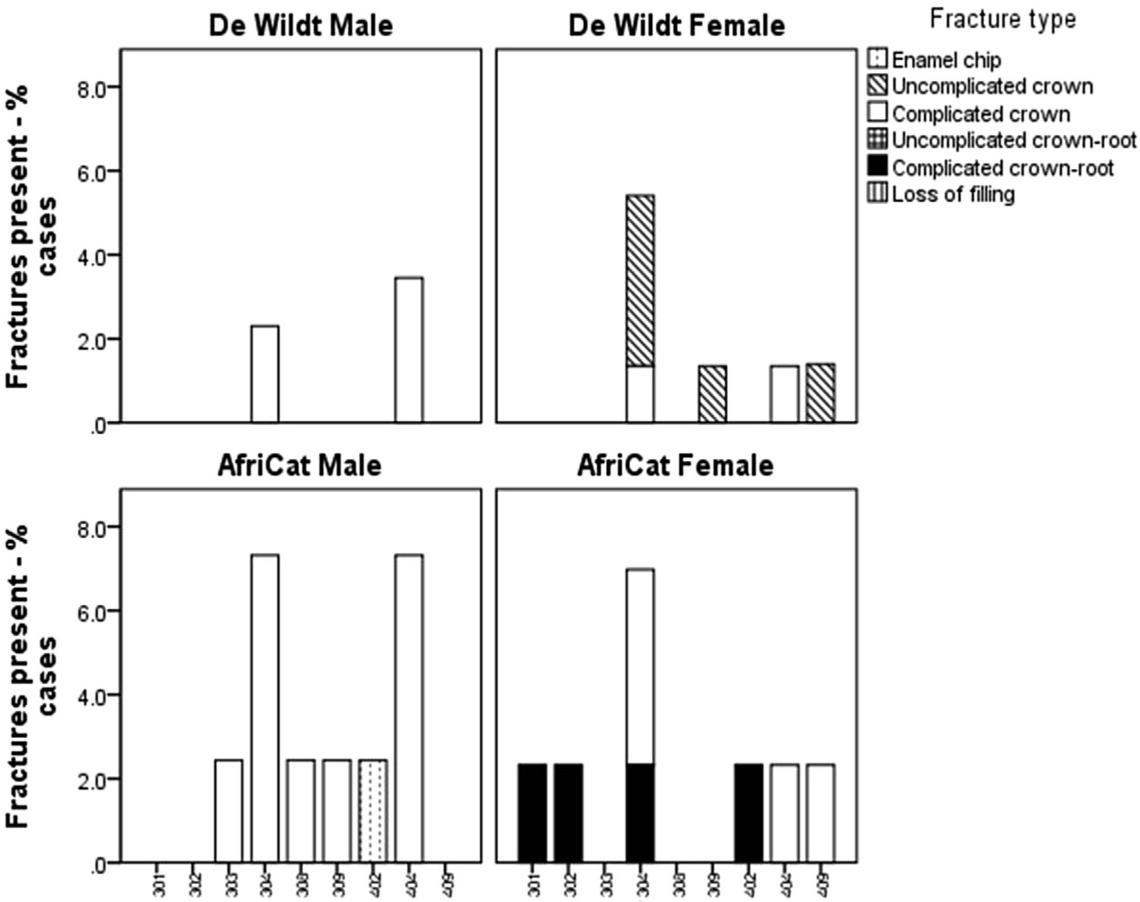

Fig. 8. The frequency and type of tooth fracture present in the mandibles of cheetahs by sex and by facility. The teeth are numbered using the modified Triadan system (Floyd, 1991).

Miller, 2015). In the Felidae, crowding of incisors often occurs with labial displacement of the 3rd mandibular incisor (Miles and Grigson, 1990), which was observed in cheetah at both facilities.

Class III malocclusions in man, dogs and cats appears to have a strong genetic basis (Niemiec, 2010; Moreno Uribe and Miller, 2015). Class III malocclusion (i.e. where the lower jaw protrudes in front of the maxilla) can be due to a too short maxilla or a too long mandible. Persian cats with a shortened maxilla are generally regarded as having class III malocclusion, but this is considered normal for the breed. Only 3/256 animals had class III malocclusion in the present study, two presenting as brachycephalic and one with mandibular prognathism. The genetic features responsible for the brachycephalic skull conformation in Persian cats (Bertolini *et al.*, 2016) could not be investigated retrospectively in the two brachycephalic cheetahs as neither animals nor the parents are currently alive, and no other siblings or offspring exist.

The one male cheetah born at DW with mandibular prognathism (class III) had no history of skull trauma that may have led to early closure of the skull sutures. This was the only time that mandibular prognathism was encountered at DW as a breeding facility, therefore the possibility of a genetic basis is unclear. We conclude that skeletal malocclusion in cheetahs is uncommon.

Absence of teeth can be congenital or acquired, but because radiographical studies were not available for all animals, the absence of teeth in most cases was difficult to explain. In 256 cheetahs evaluated, 67 (26.17%) presented with an absent tooth at the first visit. Follow up visits for several years (data not shown) confirmed the absence of incisors to be mostly the result of trauma.

At both facilities, cheetah incisors showed significant wear of enamel and dentine that often extended below the level of the gingiva, leaving only dental root rests in the jaw bone.

Second maxillary premolar teeth are not in occlusion with opponent teeth, and thus seldom worn. Absence of these teeth in cheetahs (Miles and Grigson, 1990; Roux *et al.*, 2009), only in the bred population of DW, is therefore postulated to be congenital.

Fig. 9. A persistent left maxillary canine tooth is seen in this young cheetah.

The 2nd maxillary premolar teeth were the only rotated teeth as commonly seen in the Felidae (Miles and Grigson, 1990).

Talon cusps in man are accessory cusps that are mainly present on the cingulum of maxillary incisors or canines. They resemble the talon of an eagle and consist of enamel, dentine and often also have a pulp chamber (Schuurs, 2013). To our knowledge, the present study makes the first report of talon-like cusps in Felidae and these were only seen in cheetahs younger than 20 months. Cheetahs and lions use incisor teeth when pulling and tearing muscle from a carcass and the increased cingulum size and talon-like cusps in young cheetahs may afford some benefit during carcass feeding, allowing a stronger grip on the meat (Van Valkenburgh, 1996).

Tooth resorption has been described in domestic cats (pets and feral) (Verstraete *et al.*, 1996; Ingham *et al.*, 2001; Reiter *et al.*, 2005; Gorrel, 2015), big cats (Kertesz, 1993; Berger *et al.*, 1996; Levin, 1996; Roux *et al.*, 2009) and in a dry cheetah skull (Roux *et al.*, 2009). Only one case of clinical tooth resorption affecting a canine tooth was seen during the initial visits. More cases of resorption were, however, encountered at both facilities during follow-up visits

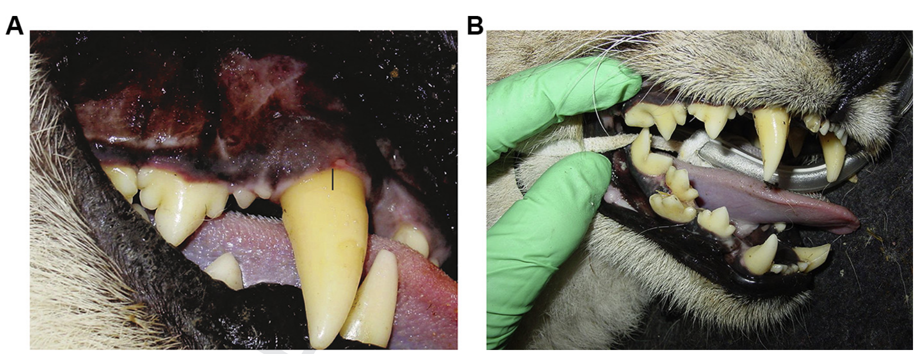

Fig. 10. Two cheetahs had supernumerary teeth, one was a supernumerary right 2nd maxillary premolar tooth (A) and the other a right mandibular 4th premolar tooth (B). Recession of the right maxillary canine tooth is visible (A) and the black line indicates the distance the gingiva has receded.

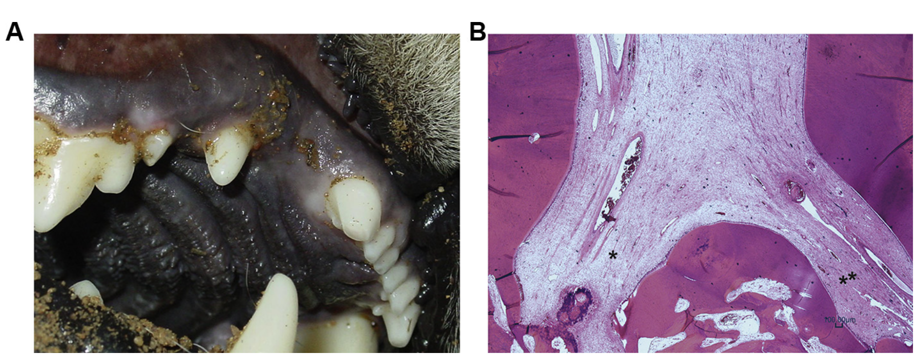

Fig. 11. (A) The appearance of a right maxillary canine tooth that was only partially erupted. (B) On histological evaluation two apices are seen (one marked * and the second marked **) in the deformed root, which was ankylosed to the underlying alveolar bone.

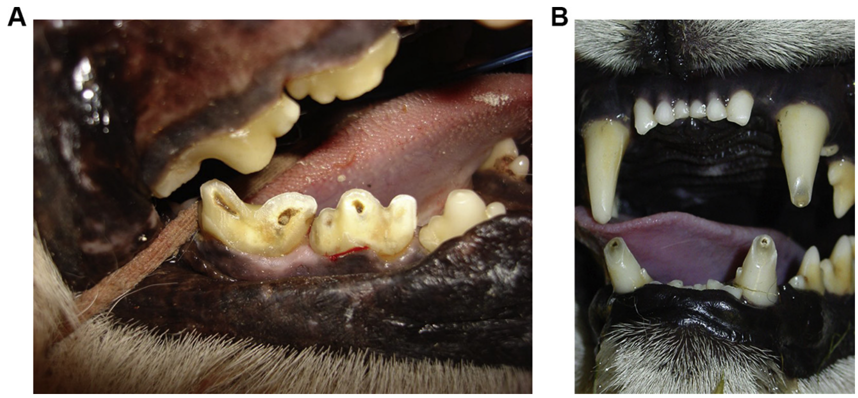

Fig. 12. (A) Typical generalized wear of most teeth seen at AF. (B) A more specific wear pattern emerged from six individuals at DW fed a moistened commercial diet. During feeding they would bite into the food while their canines then made contact with the bottom of the stainless steel bowl and removed sufficient enamel and dentine to create wear facets which even exposed the pulp.

on the 256 animals in this study (data not presented). Although radiography is necessary for optimal evaluation of the presence and extent of tooth resorption (Verstraete *et al.*, 1998), tooth resorption appears to occur infrequently in cheetahs.

Tooth fractures, especially complicated fractures with pulp exposure, occurred commonly, especially in the AF cheetahs. One explanation could be the older ages of animals at AF compared with DW, as fractures were shown to increase with age. Pulpitis as a result of complicated fractures leads to pulp necrosis with possible abscess formation, periapical granulomas, radicular cysts or even osteomyelitis (Wiggs and Lobprise, 1997).

Persistent deciduous teeth in dogs and cats may lead to malocclusion and increase the risk of periodontitis (Niemiec, 2008). Three adult cheetahs had persistent deciduous teeth, although it is generally

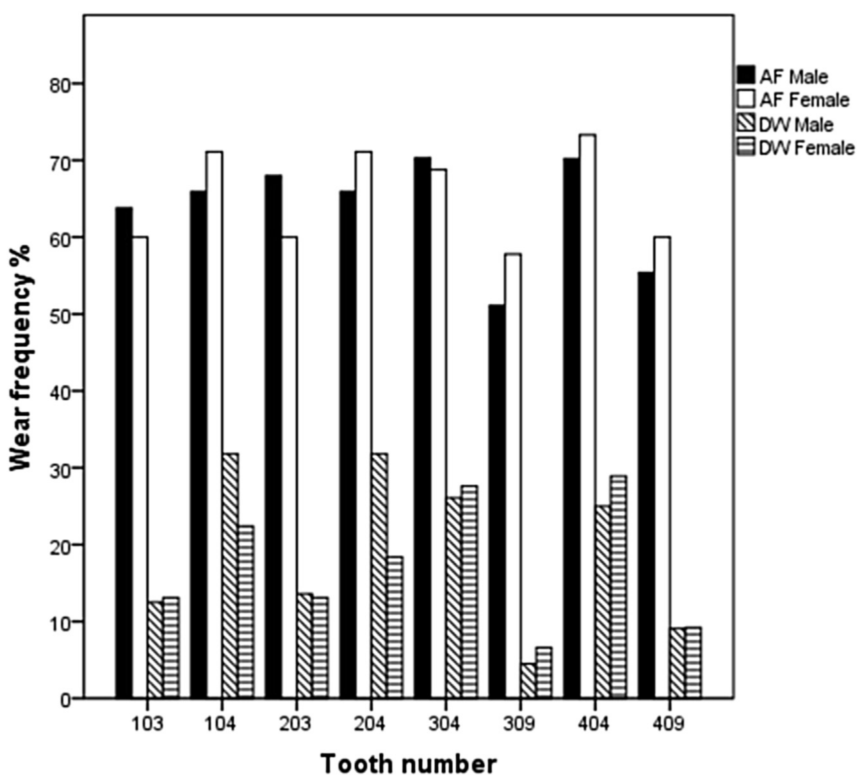

Fig. 13. Comparing wear frequencies of the eight teeth found with wear at DW with those of the AF facility. The teeth were in the right maxilla: 3rd incisor (103), canine (104), in the left maxilla: 3rd incisor (203), canine (204), in the left mandible: canine (304) and molar (309) and in the right mandible: canine (404) and molar (409).

accepted that eruption of all of the permanent teeth should be completed by 8 months (Wrogemann, 1975).

Supernumerary teeth occur in the Felidae (Miles and Grigson, 1990), including a supernumerary mandibular incisor described in a cheetah (Roux *et al.*, 2009). The present study provides the first re-cord of a supernumerary 4th mandibular premolar and a 2nd maxillary premolar teeth in cheetahs.

The ankylosed canine tooth found in one cheetah is postulated to be the result of trauma during eruption.

Periodontal disease in this study was defined as periodontal pockets measuring > 3 mm, recession and furcation lesions. Recession of the gingiva was the most common, which, together with periodontal disease overall, increased with age in cheetahs from both facilities. The cheetahs from AF were significantly older than those at DW and consequently gingival recession was more common in the population from AF. The significant recession present in the AF population cannot, however, be explained by age alone. The substrate of the enclosures of the AF animals has a high sand content and the animals usually drag their food though the sand to a place where they will lie down and feed. We propose that the sand induces the extensive hard tissue wear and irritates the gingiva around the teeth, especially that around the prominent canines, resulting in pronounced gingival recession.

Fig. 14. A pink discoloured right maxillary canine tooth from a female AF cheetah. Recession of the gingiva of this canine tooth is also very distinct and the black line indicates the distance the gingiva has receded.

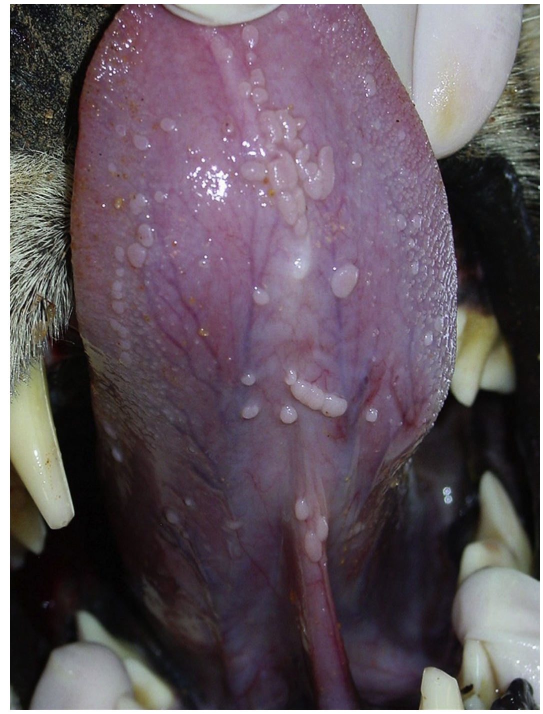

Fig. 15. Several ventral tongue proliferations on the ventral surface of an AF cheetah. These lesions were identified as be-ing caused by a unique feline papilloma virus.

Tooth wear in this study was classified either as attrition or abrasion. Attrition is the physiological wear of dental hard tissue through occlusal contact between maxillary and mandibular teeth, while abrasion is the wearing of dental hard tissue through contact between teeth and exogenous abrasive materials. Generalized abrasion of the teeth, commonly associated with pulp exposure, was more commonly seen at AF and ascribed to the sand contaminated food (see above). Attrition, the most common tooth wear category at DW, was most frequent in the mesial aspect of the maxillary canines, distal aspect of the maxillary 3rd incisor and the mesial and distal aspects of the mandibular canines. Both mandibular molar teeth usually presented with attrition (Fig. 13). During lateral excursion (side-to-side movement of the mandible) attrition is initiated. Six individuals at DW showed abrasion affecting the maxillary and mandibular canines with pulp exposure, most probably the result of long term feeding from stainless steel bowls. Teeth tended to make contact with the base of the bowl during feeding resulting in loss of enamel and dentine.

The pink–grey tooth discolouration of some teeth usually indicates a necrotic tooth pulp, most probably the result of dental trauma sustained during bowl feeding and fighting. Intra-pulpal haemorrhage leads to haemoglobin related pigments being trapped in the dentine with resultant discolouration (Boy *et al.*, 2016).

Very few animals at either facility exhibited enamel defects. When present, these mainly affected the canines and, infrequently, the maxillary 4th premolar teeth and incisors. These lesions might have been the result of pyrexia during tooth development or localized inflammatory scenarios such as trauma at an early stage of a tooth's development (Boy *et al.*, 2016).

Non-specific palatal ulcers were found infrequently in the cheetah of both facilities. The aetiopathogenesis of these lesions is not clear, although trauma is a likely cause.

Feline papilloma viruses (FPVs) are recorded in a variety of big cats (Sundberg *et al.*, 2000; Rector *et al.*, 2007), most noticeably the snow leopard (*Panthera uncia*) (Mitsouras *et al.*, 2011). The ventral tongue warts in AF cheetahs were caused by a unique FPV, confirmed by polymerase chain reaction (PCR) evaluation of a 470 base pair region of the E7 viral oncogene on tissue stored in liquid nitrogen (Brettschneider *et al.*, 2015)

In conclusion, the present study confirms that chee-tahs in captivity, whether wild caught or born in captivity, can, apart from FPE, suffer an array of non-neoplastic OMFD's similar to those seen in domestic and other big cats. Some of these conditions, most notably those affecting the skeleton, probably have a genetic background and by careful breeding se-lection can be removed from the breeding lines. Dental conditions are most commonly trauma related, caused by fighting (e.g. with camp mates or through fences), feeding soft diets from steel bowls, and excessive sand on food. Systemic disease with pyrexia may result in dental enamel defects if it occurs during the early months of dental hard tissue formation. As some of these conditions can cause pain it is advised that chee-tahs in captivity be screened annually or biennially for any of the dental diseases described above.

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