Dental Pathology in a Wild Serval (*Leptailurus serval*) Population

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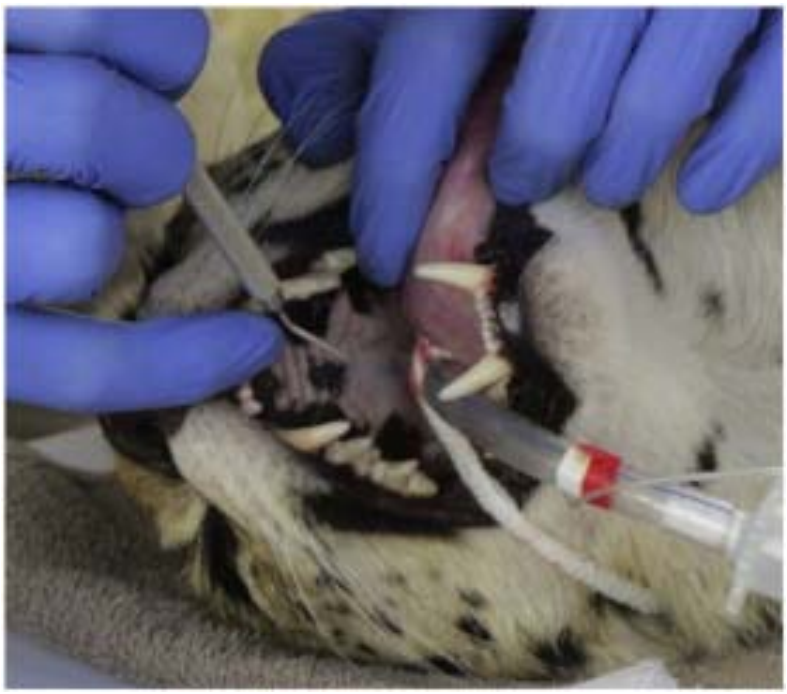
Summary

Members of the family Felidae suffer from a wide range of dental, oral and maxillofacial conditions that can cause significant morbidity and mortality. Although many dental, oral and maxillofacial anomalies of the domestic cat (*Felis catus*) also occur in wild felines, we could find no investigations of these conditions in servals (*Leptailurus serval*). The objective of this study was to describe the dental, oral and maxillofacial pathology of a wild serval population in South Africa. Detailed extraoral and intraoral examinations and full-mouth dental radiographs on 30 wild servals revealed 14 different dental conditions but no other oral or maxillofacial pathology.

Graphical abstract



Keywords: Dental; maxillofacial, pathology; Oral; servals

Introduction

The serval (*Leptailurus serval*) is a medium-sized, slender, spotted wild cat with particularly long legs, short tails and large ears that is endemic to Africa. As an adaptation to hunting small mammalian and avian prey, servals have large pinnae, well-developed ear bullae and a lightly built skull, especially in comparison with the similarly sized caracal (*Caracal caracal*) (Hunter and Bowland, 2013). Serval dentition is typically felid with the dental formula $2 \times \mathrm{I}\ \frac{3}{3}, \mathrm{C}\ \frac{1}{1}, \mathrm{PM}\ \frac{3}{2}, \mathrm{M}\ \frac{1}{1} = 30$ (Colyer, 1990). In contrast to several other wild felines (Verstraete *et al.*, 1996), the second maxillary premolar teeth appear to be always present in servals (Skinner and Chimimba, 2005).

Members of the family Felidae suffer from a wide range of dental, oral and maxillofacial conditions that can cause significant morbidity and mortality. Up to 85% of domestic cats (*Felis catus*) older than 3 years suffer from periodontal disease (Brannan, 2006). In one study of 147 domestic cats, 72% had periodontitis, 68% missing teeth, 67% tooth resorption (TR), 51% retained roots and 8% had endodontic disease (Lommer and Verstraete, 2001). Although the prevalence of dental disease in domestic cats is known to be high, limited research has been performed to determine the prevalence of dental, oral and maxillofacial disease in wild felids. A recent study described the oral, maxillofacial and dental diseases of 256 captive cheetahs (*Acinonyx jubatus*) in South Africa and Namibia (Steenkamp *et al.*, 2018). The skulls of lions (*Panthera leo*), leopards (*Panthera pardus)*, cheetahs, California bobcats (*Lynx rufus californicus*), cougars (*Puma concolor*) and Eurasian (*Lynx lynx lynx*) and Iberian lynx (*Lynx pardinus*) have been visually and, sometimes, radiographically evaluated for signs of dental and maxillofacial pathology (Berger *et al.*, 1996; Kvam, 2009; Pettersson, 2010; Aghashani *et al.*, 2016; Collados *et al.*, 2018). However, we could not find any detailed study of the dental, oral or maxillofacial pathology in servals. As servals are frequently kept in captivity and occasionally as household pets, knowledge of the oral, dental and maxillofacial pathology in this species would greatly assist in improving preventive care practices and the welfare of captive servals.

Materials and Methods

The servals that were captured occur naturally on the Sasol Synfuels property in Secunda, Mpumalanga, Republic of South Africa, at the geographical location 26° 33'S, 29° 10'E (Fig. 1). The servals roam freely in the Secunda area, including the 3,000 ha Sasol Synfuels property, which consists of an industrial plant surrounded by disturbed wetland and grassland. A recent ecological survey found that servals in Secunda occur at much greater densities than have been recorded elsewhere (Loock *et al.*, 2018). As part of this long-term ecological study, servals were captured and anaesthetized for collaring and sample collection over three 5-day periods during spring, summer and autumn from September 2017 to March 2018. This opportunity was utilized to document the dental, oral and maxillofacial pathology of a wild serval population.

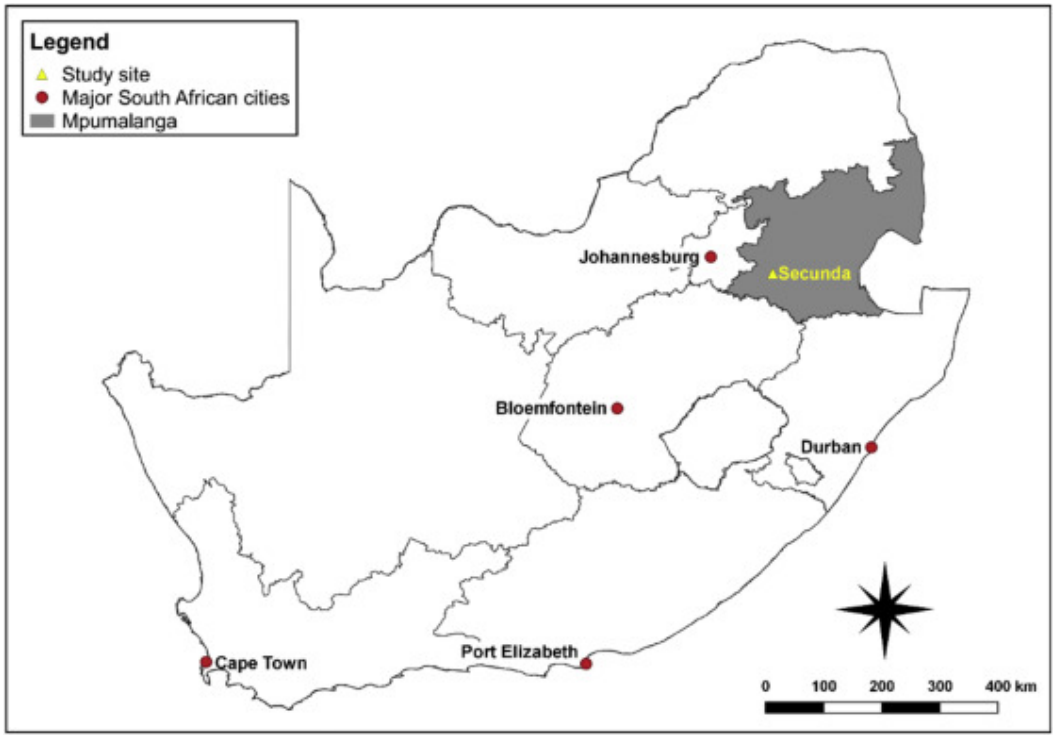


Fig. 1. Map showing location of study site: Sasol Synfuels, Secunda, Mpumalanga, Republic of South Africa.

Baited traps, consisting of a cage (length 2 m, width 0.8 m and height 0.8 m) with a guillotine door connected to a footpad were used to capture the servals. The bait, a fresh helmeted guinea fowl (*Numida meleagris*) carcass, was strung from the top of the trap at the opposite end to the door, ensuring that any serval lured into the trap would step on the footpad and trigger the guillotine door. Camouflage netting was used to cover the trap, providing shade and minimizing stress to the animal caused by researchers approaching the cage. The traps were erected at various locations on the property, based on serval densities determined by camera trap and global positioning system collar data, and were monitored twice daily, at the beginning and end of each capture session. This capture protocol was approved by the Animal Ethics Committee of the University of Pretoria (protocol number EC040-14) and a capture permit was obtained from Mpumalanga Tourism and Parks Agency (permit number 5467).

Following capture of a serval, the cage was loaded onto a field vehicle and transported to an examination area. Each animal was remotely immobilized utilizing a 3 ml blowdart and blowpipe (DANiNJECT, Kolding, Denmark). The anaesthetic protocol, approved by the Animal Ethics Committee of the University of Pretoria (V108-17), formed part of a separate study (Blignaut *et al.*, 2020). Following immobilization, the serval was moved from the trap to an examination table where it was managed by a dedicated team of anaesthetists. Each serval was scanned for the presence of a microchip and, if none was detected, one was inserted subcutaneously between the scapulae. A body condition score was recorded using a five-point scale (American Animal Hospital Association, 2020) (Supplementary Fig. 1). Full-mouth dental photographs were taken using a handheld digital camera, and an age category (juvenile, subadult or adult) was assigned to each serval (Table 1). Servals that were recaptured over the course of the study were excluded from the data evaluation at

subsequent captures unless a change of age category between examinations was apparent. As a serval's dietary requirements and behaviour differ at different life stages, variation in the dental, oral and maxillofacial pathologies may occur.

Table 1. Criteria for designation of age category for each serval

Age category	Criterion
Juvenile	Deciduous or mixed dentition
Subadult	Permanent dentition in which the apices of the maxillary canines are still open
Adult	Permanent dentition in which the apices of the maxillary canines are closed

Complete extraoral and intraoral examinations were performed on each animal and the findings (Table 2) recorded on a feline dental chart. During the extraoral examination, the entire head was palpated, and the mandibles manipulated to detect abnormalities. The intraoral examination began with inspection of the oropharynx, tonsils, palate, tongue and buccal mucosa. Each tooth was then examined individually. Calculus and gingivitis indices were scored for each tooth (Schumacher, 1993; Hefferen, 1994). Periodontal pocket depth, gingival recession and furcation defects were measured using a periodontal probe. A dental explorer was used to investigate enamel defects, crown fractures, TR and tooth mobility. The oral cavity was carefully inspected for masses or other soft tissue lesions.

Table 2. Oral scoring system used for dental, oral and maxillofacial evaluation of wild servals

Pathology	Score	Description
Calculus index score (Hefferen, 1994)	0	No calculus
	1	0–24% crown coverage
	2	25–49% crown coverage
	3	50–74% crown coverage
	4	75–100% crown coverage
Gingivitis index score (Schumacher, 1993)	0	Healthy gingiva
	1	Slightly inflammed
	2	Delayed bleeding on probing
	3	Profuse bleeding on probing or bleeds when touched lightly
Mobility (Schumacher, 1993)	0	No mobility
	1	Horizontal movement of <1 mm
	2	Horizontal movement >1 mm
	3	Vertical and horizontal movement.
Dental fractures (Verstraete *et al.*, 1996)	1	Uncomplicated crown fracture: a fracture affecting enamel and dentine but not exposing the pulp
	2	Complicated crown fracture: a fracture affecting enamel and dentine and exposing the pulp
	3	Root fracture: a fracture affecting dentine, cementum and pulp
	4	Uncomplicated crown-root fracture: a fracture affecting enamel, dentine and cementum but not exposing the pulp
	5	Complicated crown-root fracture: a fracture affecting enamel, dentine and cementum and exposing the pulp
		Staining of dentine by extrinsic or intrinsic sources

Pathology	Score	Description
Tooth discolouration (Boy *et al.*, 2016)		Tooth discolouration
	0	Tooth discolouration absent
	1	Tooth discolouration present
Tooth wear (Verstraete *et al.*, 1996)		Rounding or flattening of the occlusal surface; exposure of dentine with or without tertiary dentine formation
	0	Tooth wear absent
	1	Tooth wear present
Enamel defect (Boy *et al.*, 2016)		Focal reduction in quantity or quality of enamel
	0	Enamel defect absent
	1	Enamel defect present
Retained deciduous root		Deciduous root still present adjacent to the corresponding permanent root
	0	Retained deciduous root absent
	1	Retained deciduous root present
Supernumerary root (Verstraete *et al.*, 1996)		Presence of a third root in a tooth that normally has two roots
	0	Supernumerary root absent
	1	Supernumerary root present
Supernumerary tooth (Verstraete *et al.*, 1996)		Presence of an additional tooth not normally included in the dental formula
	0	Supernumerary tooth absent
	1	Supernumerary tooth present
Abnormal root morphology (Aghashani *et al.*, 2016)		Any irregular structure or formation of a root
	0	Abnormal root morphology absent
	1	Abnormal root morphology present
Tooth rotation (Steenkamp *et al.*, 2018)		Movement of a tooth on its long axis
	0	No tooth rotation present
	1	Tooth rotation present (in approximate degrees)
Tooth resorption (Pettersson, 2010)		Progressive loss of dentine and cementum or enamel
	0	Tooth resorption absent
	1	Tooth resorption present
Periapical lesion (Verstraete *et al.*, 1996)		Presence of periapical bone loss
	0	Periapical lesion absent
	1	Periapical lesion present
Capture injuries		Any lesion deemed to be result of trapping

A total of 10 radiographs were made to obtain a full-mouth radiographic set of each serval, using a handheld dental X-ray unit (Aribex NOMAD, Aribex, Charlotte, North Carolina, USA) with 2.3 mA and 60 KV; dental phosphor imaging plates (sizes 2 and 4) and the CR-7 dental radiographic reader and software (iM3, Vancouver, Washington, USA, available via DIAG Import and Export CC, Republic of South Africa). The radiographic views employed to obtain full-mouth radiographs are listed in Table 3.

Table 3. Intraoral radiographic views used to obtain a full-mouth radiographic set (Harvey and Flax, 1992) of each serval

Structures imaged	Radiographic view
Incisor and canine teeth	Intraoral rostrocaudal bisecting angle
Canine teeth	Intraoral lateral bisecting angle
Maxillary premolar and molar teeth	Modified intraoral lateral bisecting angle
Mandibular premolar and molar teeth	Intraoral parallel

The dental terminology used in this study includes the descriptive names of teeth, according to the *Nomina Anatomica Veterinaria* (International Committee of Veterinary Gross Anatomical Nomenclature, 2017), and the modified Triadan system (Floyd, 1991). Statistical analyses were performed using commercially available software (MiniTab 18.1; MiniTab Inc.; USA) and the results interpreted as significant at $p < 0.05$.

Results

Twenty-nine individual servals were captured. Five servals were recaptured during the course of the study and only one recapture was included (as this serval had changed age-category between captures) to make 30 data sets available for evaluation. A total of 902 (of an expected 900) teeth were examined, with no teeth absent. Nineteen examined servals were female (63%) and 11 were male (37%). Two captured servals were classified as juveniles (7%), four as subadults (13%) and 24 as adults (80%). Sixty percent of servals with dental pathology were female and 40% were male. Eighty-four percent of affected servals were adults, 12% subadults and 4% juveniles. The number and percentages of dental lesions, as well as the number of affected male and female servals of various age groups, are summarized in Table 4.

Table 4. Frequency of dental lesions in various categories of serval

Lesion	No. serval (%)	No. adults	No. subadults	No. juveniles	No. females	No. males	No. affected teeth	Most frequently affected teeth
Tooth wear	20 (67%)	19	0	1	14	6	66	Maxillary canine teeth
Uncomplicated crown fracture	3 (10%)	3	0	0	0	3	3	Maxillary canine teeth
Complicated crown fracture	1 (3%)	1	0	0	1	0	2	Left maxillary and mandibular canine teeth
Root fracture	3 (10%)	3	0	0	1	2	3	Maxillary incisor teeth
Periapical radiolucency	1 (3%)	1	0	0	1	0	2	Left maxillary and mandibular canine teeth
Crown discolouration	1 (3%)	1	0	0	1	0	2	Left maxillary and mandibular canine teeth

Lesion	No. serval (%)	No. adults	No. subadults	No. juveniles	No. females	No. males	No. affected teeth	Most frequently affected teeth
Mobility	2 (7%)	2	0	0	1	1	3	Maxillary second premolar teeth
Retained deciduous root	2 (7%)	1	1	0	1	1	4	Maxillary second and third premolar teeth
Tooth resorption	1 (3%)	1	0	0	1	0	2	Maxillary incisor teeth
Supernumerary tooth	3 (10%)	3	0	0	0	3	3	Mandibular premolar teeth
Supernumerary root	5 (17%)	4	1	0	3	2	6	Maxillary third premolar teeth
Tooth rotation	1 (3%)	1	0	0	1	0	2	Maxillary second premolar teeth
Abnormal root morphology	6 (20%)	6	0	0	0	6	12	Maxillary canine teeth
Enamel defect	1 (3%)	1	0	0	0	1	1	Left mandibular canine tooth

Tooth Wear

Tooth wear was the most commonly observed dental anomaly in both male and female servals (Fig. 2). Only mild occlusal wear, with no pulp exposure or tertiary dentine formation, was noted in 20 servals (67%), affecting 66 teeth (7%) overall. One juvenile and 19 adults, but no subadults, displayed mild tooth wear. The teeth most commonly affected were the maxillary incisor teeth (39% of worn teeth), maxillary canine teeth (29%), mandibular canine teeth (15%) and maxillary third premolar teeth (11%) (Fig. 3).

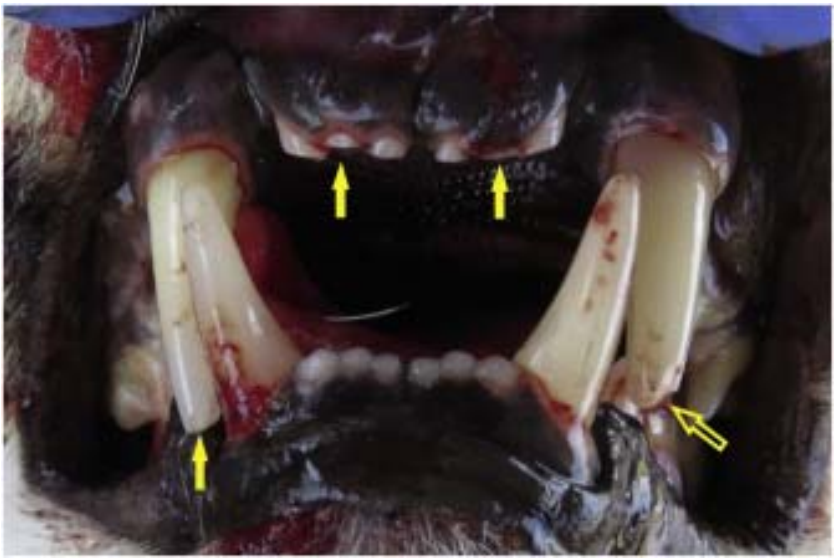


Fig. 2. Tooth wear of maxillary incisor teeth and maxillary right canine tooth (solid arrows) in a wild serval. An uncomplicated crown fracture also present in left maxillary canine tooth (outlined arrow). Bleeding due to superficial facial wounds sustained when trapped animal was approached for immobilization.

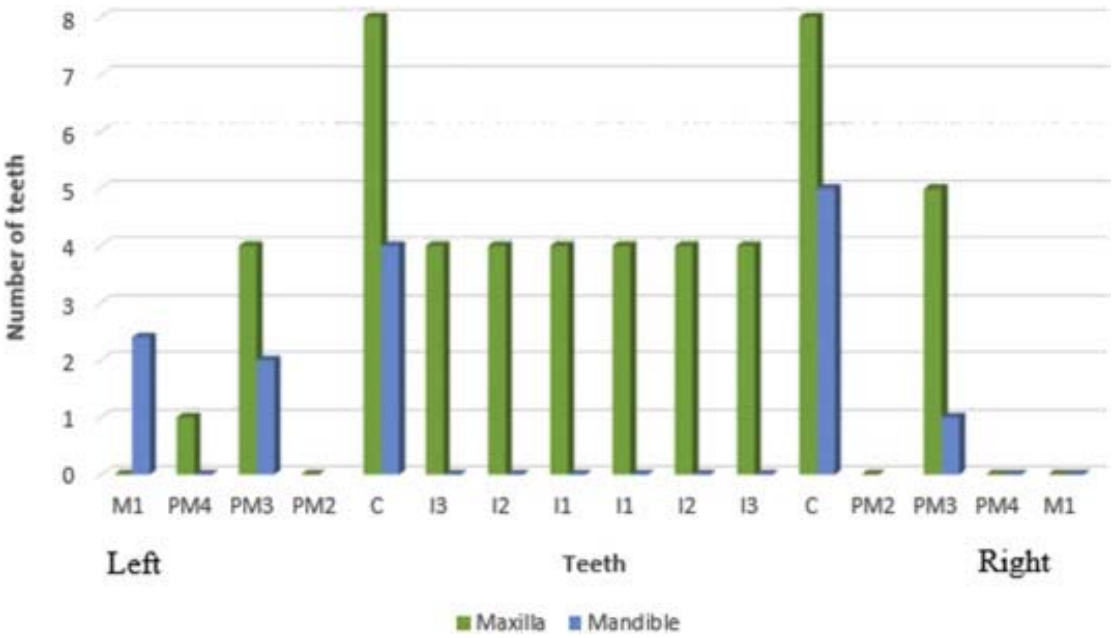


Fig. 3. Distribution of tooth wear in dentition of wild servals.

Supernumerary Roots

Supernumerary roots, all identified as slender palatal third roots of maxillary third premolar teeth, were present in five (17%) of the captured servals (Fig. 4). These supernumerary roots were unilateral (right) in four servals and bilateral in one animal. Ten percent of the maxillary third premolar teeth, evaluated radiographically, had a supernumerary root. There was no sex predilection for this anomaly.

Fig. 4. Supernumerary third root (arrow) at right maxillary third premolar tooth in a wild serval.

Supernumerary Teeth

Three supernumerary teeth were found, one in each of three adult male servals (10%) (sex: $p = 0.028$). The supernumerary teeth were all unilateral mandibular premolar teeth, situated rostral to the third premolar tooth (Fig. 5). One supernumerary tooth was in the left mandible and two were in the right mandible, with one being unerupted (Fig. 6).

Fig. 5. Supernumerary premolar tooth (arrow) of the left mandible in a wild serval.

Fig. 6. Unerupted supernumerary premolar tooth (arrow) in right mandible of a wild serval.

Abnormal Root Morphology

Abnormal tooth morphology, considered to be any irregular structure or formation of the crown of the tooth, root of the tooth, or both (Aghashani *et al.*, 2016), was diagnosed radiographically in six servals. In five individuals, maxillary canine teeth with squared root apices were present bilaterally (Fig. 7A). One serval had a maxillary right canine tooth with a prominent indentation at the mesial aspect of the root (Fig. 7B). The left maxillary canine tooth in the same individual had a squared root apex. Therefore, 20% of captured servals and 1.2% of examined teeth had abnormal root morphology. This abnormality was only detected in adult male servals (sex: $p = 0.022$).

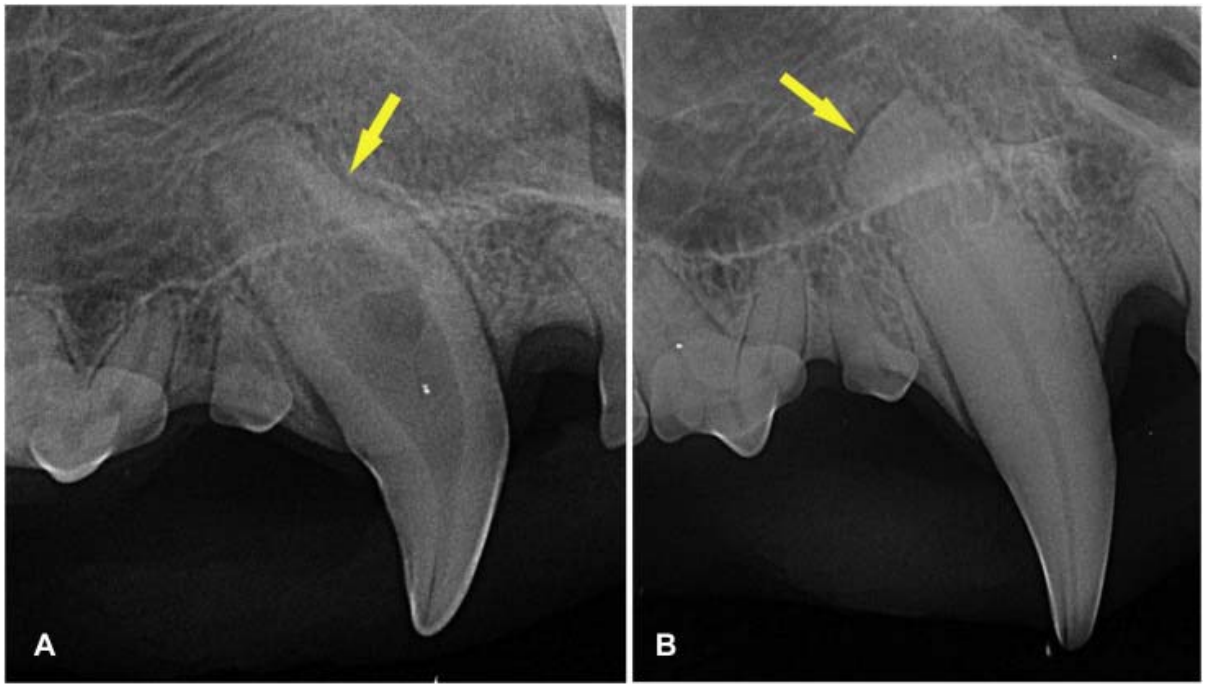


Fig. 7. Abnormal indentation (A) and square apex (B) of right maxillary canine teeth in two adult male wild servals.

Rotated Teeth

One adult female presented with bilateral rotation of the maxillary second premolar teeth around their long axes, by approximately 30°, so that the mesial aspect of the tooth was oriented more palatal and the distal aspect more buccal than normal.

Retained Deciduous Roots

Two servals, one adult female and one subadult male, had retained fractured deciduous roots adjacent to the roots of the permanent dentition. In the male, these additional roots were present bilaterally adjacent to the maxillary third premolar teeth (Fig. 8A), and in the female, the additional roots were present bilaterally adjacent to the maxillary second premolar teeth (Fig. 8B). All of these structures had thick dentinal walls, a periodontal ligament space and a root canal, and were situated adjacent to the corresponding

permanent tooth roots and thus appeared to be retained fractured deciduous roots. No periapical pathology was evident radiographically.

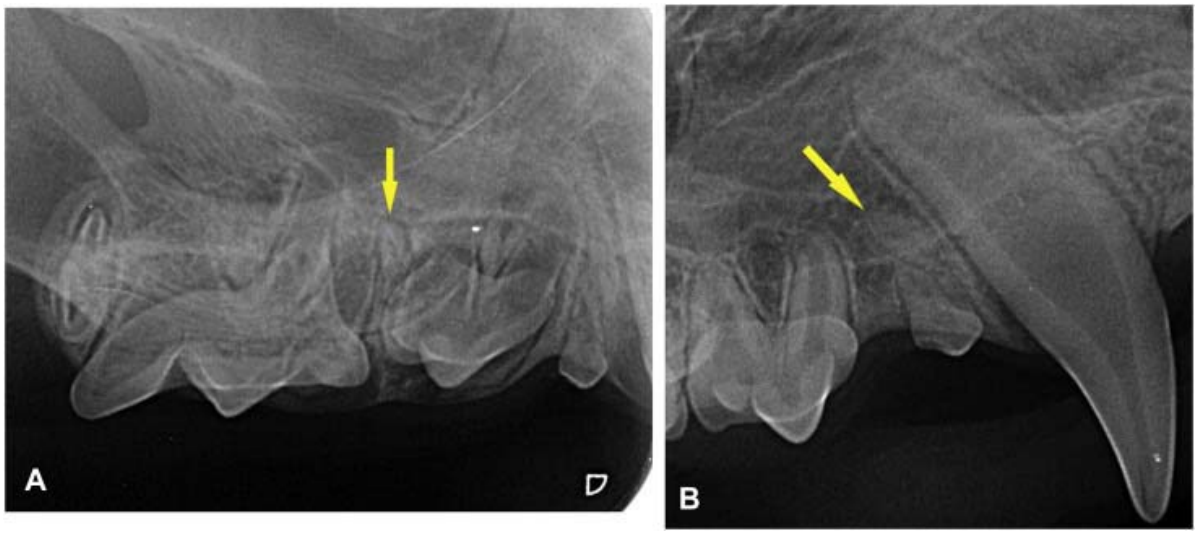


Fig. 8. Retained fractured deciduous roots at right maxillary third premolar tooth in a male wild serval (A) and right maxillary second premolar tooth in a female wild serval (B).

Enamel Defects

One adult male serval had an enamel defect on the crown of the left mandibular canine tooth (Fig. 9).

Fig. 9. Small enamel defect (arrow) at distal aspect of crown of left mandibular canine tooth of a male wild serval.

Tooth Resorption

Only one case of TR was diagnosed among the captured servals. Type II TR, defined as progressive loss of dental hard material with narrowing or loss of the periodontal ligament space and decreased radiopacity of the roots (American Veterinary Dental College, 2012), was evident at the roots of the first and second left maxillary incisor teeth in one adult female. A root fracture was visible radiographically at the second maxillary incisor tooth with an associated mobility score of 2 (Fig. 10).

Fig. 10. Type II tooth resorption of the left maxillary first and second incisor teeth with associated root fracture (arrow) of second incisor tooth of an adult female wild serval.

Dental Fractures and Tooth Discolouration

Dental fractures were noted in seven captured servals (23%), affecting eight teeth (0.9%). The prevalence of dental fractures was similar in males and females. Maxillary teeth were affected more frequently than mandibular teeth (87% vs 13%) with maxillary canine teeth most commonly affected (Fig. 11). Uncomplicated crown fractures, complicated crown fractures, as well as root fractures were diagnosed. Root fractures were noted in three individuals, each with a fracture of a single tooth evident radiographically. The affected teeth included left maxillary first and second incisor teeth and a left maxillary second premolar tooth. Uncomplicated crown fractures of maxillary canine teeth accounted for three of the eight dental fractures noted. In one adult female serval, complicated crown fractures were observed in the left maxillary and mandibular canine teeth, with associated grey discolouration of the crowns.

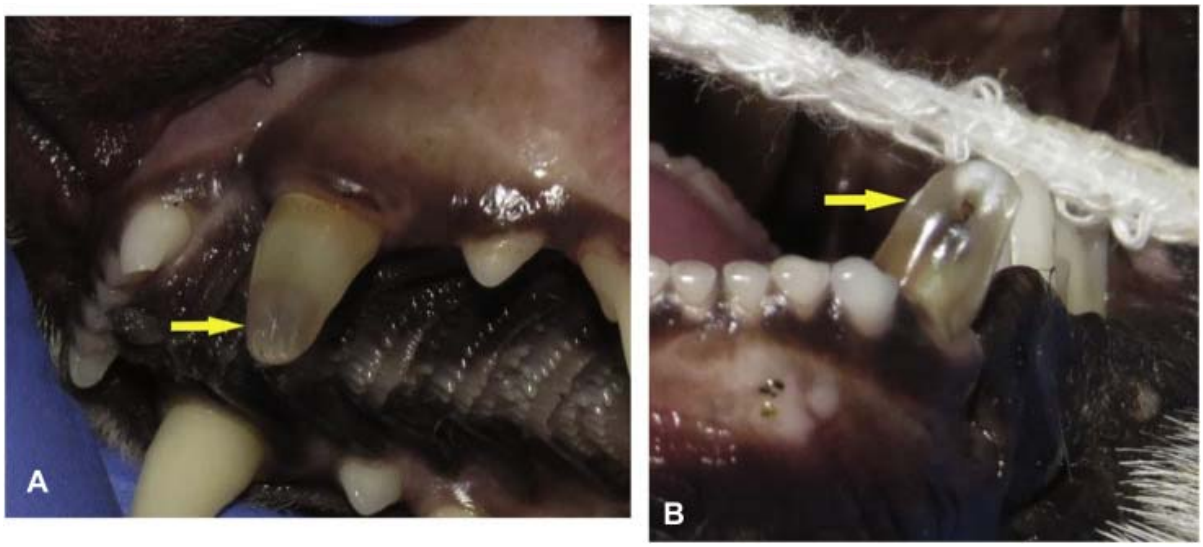


Fig. 11. Complicated crown fractures with grey discolouration of the left maxillary (A) and mandibular (B) canine teeth in an adult female wild serval.

Periapical Lesions

Periapical lesions were noted radiographically in only one adult female that had complicated crown fractures of the left maxillary and mandibular canine teeth (Fig. 12).

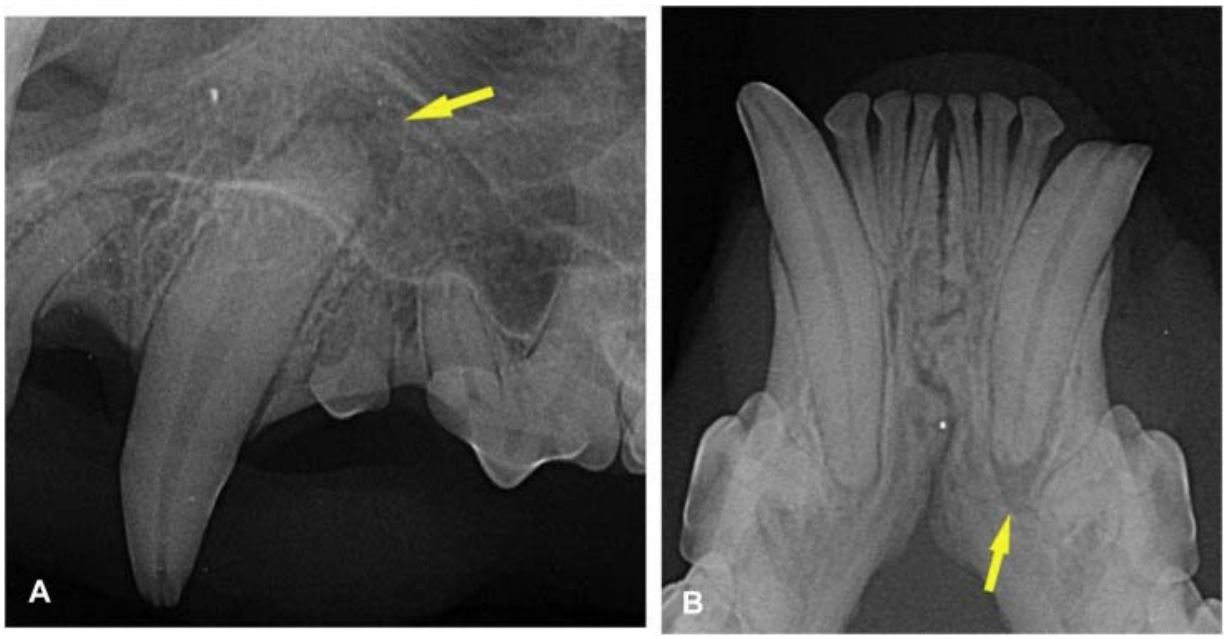


Fig. 12. Periapical radiolucencies in left maxillary (A) and mandibular canine (B) teeth of a female wild serval due to complicated crown fractures.

Mobility

Mobile teeth were found in one adult female and one adult male serval. The male's left maxillary second premolar tooth and the female's left maxillary second incisor tooth both had a mobility score of 2 due to root fracture (Fig. 13).

Fig. 13. Root fracture (arrow) of left maxillary second premolar tooth in a male wild serval.

Calculus and Gingivitis

Mild dental calculus accumulation was found in 27 servals (90%), but on only 85 teeth (9%) (Fig. 14). Seven servals (23%) had mild focal gingivitis. Bleeding on probing, indicating a gingivitis index score of 2, occurred at one tooth in each of five servals, two in one serval and six in another serval.

Fig. 14. Mild calculus accumulation and mild focal gingivitis (arrow) in a wild serval.

Body Condition

Twenty-nine of the 30 servals included in this study had a body condition score of 3 or 3.5 out of 5. Only one adult female had a body condition score of 2.5. Since the body condition was similar among all captured servals regardless of the presence of dental pathology, sex or age, it was not possible to evaluate the association of these factors.

No oral tumours or inflammatory soft tissue lesions were seen on clinical examination or radiographs.

Capture Injuries

Due to the inherent stress of trapping and darting, mild capture injuries were sustained by several animals. The most common injury was abrasion of the skin of the head. On intraoral examination, small gingival lacerations were diagnosed in five servals and small lingual lacerations were found in two animals. In one serval, a complicated crown fracture of the right maxillary third incisor tooth was diagnosed on intraoral examination. It was assumed that the fracture had occurred at the time of darting as the pulp was bleeding on examination. The affected tooth was extracted. A footpad laceration, which was treated by cleaning and suturing, was found in one captured serval.

Discussion

This report describes the dental pathology in wild servals captured on the Sasol Synfuels Operations plant in Secunda, Mpumalanga, Republic of South Africa. Fourteen different dental pathologies were diagnosed, but no other oral or maxillofacial pathology was identified.

The most common dental pathology observed among the captured servals was tooth wear. Only minor wear of occlusal surfaces was evident in affected teeth. The pattern of tooth wear of the study population was more similar to that recorded for the California bobcat (Aghashani *et al.*, 2016) than that recorded for feral cats (Verstraete *et al.*, 1996) or the Iberian lynx (Collados *et al.*, 2018). As in the California bobcat, the canine and incisor teeth were the most commonly affected teeth (Aghashani *et al.*, 2016). The maxillary third premolar teeth, which were the most frequently affected in a feral cat population on Marion Island (Verstraete *et al.*, 1996), were also often affected in the current study (Fig. 3). Even though the distribution of tooth wear differed in the previous studies, both studies concluded that the wear was most likely related to diet. It is possible that the same may be true for wild servals. Since the serval's diet consists of at least 80% rodents (Skinner and Chimimba, 2005), it is conceivable that tooth wear may be due to abrasion from the rodents' hair coat. Rodents are burrowing animals and thus sand will accumulate among the hair fibres. Sand and hair can be abrasive to teeth (Holmstrom, 1998). Serval often eviscerate the carcass and tear it into small pieces that require little mastication before swallowing (Skinner and Chimimba, 2005). The serval's feeding behaviour may therefore explain the frequency of wear of rostrally situated teeth.

Supernumerary roots are an anatomical variation occasionally seen in felines. The teeth most commonly affected in felines include the maxillary molar teeth, maxillary third premolar teeth and mandibular molar teeth (Verstraete *et al.*, 1996; Verstraete and Terpak, 1997; Aghashani *et al.*, 2016; Collados *et al.*, 2018). Supernumerary roots of maxillary molar teeth were not identified in the current study, but since live animals were studied and the number of roots of maxillary first molar teeth is difficult to assess on radiographs, these supernumerary roots may not have been identified. A prevalence of 10% of maxillary third premolar teeth with a supernumerary third root is very similar to previous studies of domestic and feral cats (Verstraete *et al.*, 1996; Verstraete and Terpak, 1997), but higher than that recorded for the Iberian lynx and California bobcat (Aghashani *et al.*, 2016; Collados *et al.*, 2018). Supernumerary roots seldom give rise to a disturbed gingival contour, which may predispose to periodontal disease (Verstraete and Terpak, 1997). However, the presence of a supernumerary root is clinically significant when a dental procedure, such as extraction, is planned. It is unlikely that a dental procedure will be performed on a wild serval, but dental radiographs must be taken when performing dental procedures on captive serval.

Supernumerary teeth have been recorded in domestic and wild felines. These include teeth rostral to maxillary second premolar teeth, rostral to mandibular third premolar teeth, caudal to mandibular molar teeth and supernumerary maxillary incisor and mandibular fourth premolar teeth (Verstraete *et al.*, 1996; Verstraete and Terpak, 1997; Kvam, 2009; Pettersson, 2010; Collados *et al.*, 2018; Steenkamp *et al.*, 2018). In Colyer's extensive work on felid skulls, he mentioned that supernumerary teeth were most commonly found in the premolar region (Colyer, 1990). The current study confirmed his findings, as the only supernumerary teeth present were premolar teeth rostral to the mandibular third premolar tooth. Supernumerary teeth are normally clinically insignificant unless they cause crowding, resulting in periodontitis, or if they remain unerupted, which may lead to the formation of a dentigerous cyst (Gioso and Carvalho, 2003). Colyer also noted in the serval specimens he examined that no teeth displayed an irregularity of position (Colyer, 1990). In the current population, this statement was largely found to be true, apart from two rotated maxillary second premolar teeth in one serval.

The small enamel defect in one mandibular canine tooth and the root indentation of one maxillary canine tooth may have resulted from localized trauma or inflammation during development of the affected teeth (Boy *et al.*, 2016). The squared root apices seen in six male servals may also have been the result of such an occurrence. However, it is also possible that squared root apices are a normal anatomical variation in male serval, as radiographs taken in a study of California mountain lion skulls in 2016 revealed many healthy maxillary canine teeth with squared root apices. Male mountain lions were found to have more teeth with this abnormal root form than female mountain lions (Aghashani *et al.*, 2017).

Another interesting radiographic finding was the presence of what appeared to be retained fractured deciduous roots. The structures in question were seen bilaterally in two individuals. In the first affected serval, the structures were adjacent to the developing distal root of both maxillary third premolar teeth, and in the second serval, the structures were adjacent to the apices of both maxillary second premolar teeth. The structures were

described as retained fractured deciduous roots as they had the shape of a tooth root, with a periodontal ligament space, a root canal and thick dentinal walls. It is possible that the corresponding deciduous teeth had root fractures prior to resorption of the roots. However, it is difficult to reconcile this notion with the fact that in both cases the condition occurred bilaterally.

The prevalence of dental fractures in this study was 23%, which is lower than previously recorded for feral cats and other wild felines (Verstraete *et al.*, 1996; Roux *et al.*, 2009; Aghashani *et al.*, 2016). Three types of tooth fractures were diagnosed, including root fractures and uncomplicated and complicated crown fractures. The two canine teeth that had complicated crown fractures displayed a grey discolouration. Intrinsic tooth discolouration occurs when haemoglobin-related pigments are deposited in the dentine following pulp haemorrhage or pulp necrosis. Due to the almost translucent nature of enamel, the colour of the underlying dentine influences the overall colour of the tooth (Boy *et al.*, 2016). The teeth affected by complicated crown fractures showed radiographic evidence of endodontic disease, including periapical radiolucency and a slightly wider pulp canal in comparison with the contralateral tooth. Two teeth were determined to be mobile during the oral examination as a result of root fractures.

Only one case of TR was diagnosed and was associated with a root fracture of the left maxillary second incisor tooth. Both the first and second left maxillary incisor teeth had evidence of type II TR, with narrowing of the periodontal ligament space and decreased radiopacity of the roots. It is possible that the root fracture occurred secondary to TR; however, since no other incidences of TR were diagnosed in the study population, it is more likely that TR was secondary to inflammation at the site of the dental fracture.

The only sign of periodontitis observed in the study population was mild focal gingivitis (periodontitis stage 1). Bleeding on probing occurred at only a few examined teeth. No periodontal pockets, furcation exposure or alveolar bone loss were diagnosed. Mild calculus accumulation was evident with most animals only displaying calculus at the maxillary fourth premolar teeth, covering less than 25% of the crown surface.

Regardless of the dental pathology, almost all of the servals had an ideal body condition. Only one adult female had a slightly lower body condition and, interestingly, had no dental, oral or maxillofacial pathology. Therefore, body condition was not significantly influenced by dental pathology in this population.

Although every effort was made to reduce the stress of the servals while in the traps, some mild capture injuries were sustained. On approach of the trap by the anaesthetic team, the serval would usually run into the side of the trap in an attempt to escape. The most common capture injury was abrasion of the skin of the facial and cranial regions. All capture complications were appropriately treated, and the recovery and release of each serval was uneventful.

Since the current study was performed on live servals rather than skulls, it was possible to evaluate the oral and maxillofacial soft tissues for lesions. Only mild focal gingivitis was observed in a small number of animals, but neither generalized gingivitis nor stomatitis was

diagnosed. To the authors' knowledge, this is only the second study of the dental, oral and maxillofacial pathology in wild felines to be performed on live animals rather than on skulls. This is significant as only pathology affecting the bone or teeth can be examined on skulls; however, the early stages of several oral diseases do not result in bony changes and some conditions exclusively affect soft tissues.

In conclusion, this study indicates that intraoral and extraoral examinations, as well as dental radiography, are important aspects of the clinical evaluation of wild felines. It is intriguing that even at the highest density of servals recorded in the literature, and with their habitat consisting predominantly of disturbed wetland and grassland, directly surrounding a highly active industrial site, minimal pathology was found. This demonstrates that even the most unexpected sectors and opportunities can be used to advance conservation efforts as well as to provide knowledge to assist in improving the husbandry of captive wild animals.

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Conflict of Interest Statement

None of the authors of this article have conflicts of interest to declare. This work was supported by Secunda Synfuels Operations, a division of Sasol South Africa, Secunda, Mpumalanga, Republic of South Africa.

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