DISEASE IN WILDLIFE OR EXOTIC SPECIES

Dental Pathology of the California Bobcat (*Lynx rufus californicus*)

A. Aghashani*, A. S. Kim*, P. H. Kass† and F. J. M. Verstraete*

*Department of Surgical and Radiological Sciences and †Department of Population Health and Reproduction, School of Veterinary Medicine, University of California, Davis, CA, USA

Summary

Skulls from 277 California bobcats (*Lynx rufus californicus*) were examined macroscopically and by radiography. The majority of the skulls were from adult animals (79.8%). The skulls were from 128 male (46.2%) and 114 female (41.2%) animals and gender was unknown for the remainder. The majority (95.6%) of teeth were present for examination. Only 16 teeth were identified as absent congenitally and 15 of these were incisor teeth. Teeth with abnormal morphology were rare (0.5%). The two most common abnormalities were unusually large crowns of the maxillary first molar teeth and bigemination of the mandibular incisor teeth. Teeth with an abnormal number of roots were uncommon (*n* = 68). Sixty-three teeth had abnormal roots, mostly the presence of two roots instead of one for the maxillary first molar tooth. The most prevalent dental lesions found in the California bobcat were attrition/abrasion (85.2%), periodontitis (56.0%) and tooth fractures (50.9%). Less common dental lesions were endodontal disease (*n* = 114 teeth) and tooth resorption (*n* = 73 teeth).

Introduction

The bobcat (*Lynx rufus*) is mid-range in size when compared with other members of the family Felidae. The average length of bobcats can range from 62 to 106 cm, with a short, rounded tail that adds 13–20 cm to this length (Grzimek, 2004). The ‘bobbed’ appearance of the tail gives the species its name. The body weight of a bobcat can range from 6 to 17 kg. With the exception of the males being larger and more muscular, there is little sexual dimorphism in this species. The current habitat range of the bobcat includes southern Canada to northern Mexico, with the majority found within the USA (Grzimek, 2004). Thirteen bobcat subspecies are recognized and the California bobcat (*Lynx rufus californicus*) is the subspecies inhabiting California, west of the Sierra Nevada. Males commonly have larger home ranges than females; male territories tend to encompass the territories of one or more females. Bobcats fight over territory, but physical aggression is generally avoided via scent marking and calling. If physical aggression does occur, it tends to happen during competition for a female exhibiting oestrus (Grzimek, 2004).

The adult bobcat has a total of 28 teeth (Fig. 1), with a dental formula of I 3/3, C 1/1, P2/2, M 1/1 = 28. The maxillary second premolar tooth in Felidae has received considerable attention in the zoological literature, as it is believed that this tooth is disappearing over the course of evolution, which is already the case in *L. rufus* (Verstraete and Terpak, 1997). Felidae are typically strict carnivores at the top of the food chain. Smaller Felidae, like the bobcat, tend to hunt rodents, rabbits and hares. They will also hunt reptiles, amphibians and birds when their preferred prey is scarce. Felidae hunt prey using powerful jaws and secodont dentition for cutting and gnawing meat. Smaller cats tend to gnaw meat off of the bone or pull the meat off in pieces to swallow whole; they complete this shearing action using their
maxillary fourth premolar and mandibular first molar teeth with an approach from the side of the mouth, rather than the front. Felidae also have a rough tongue covered with conical papillae used to lick bones clean (Grzimek, 2004). The integrity and functionality of bobcat dentition is an integral component of their overall health. Without functional dentition, their ability to hunt and kill prey is greatly diminished and can contribute to morbidity and mortality of the species.

In previous years, concerns over the extinction of certain species of wild Felidae have driven conservation efforts. Many species of Felidae, especially in the USA, have been historically persecuted by farmers due to perceived threats to livestock, as true predation rates tend to be fairly low (Grzimek, 2004). The most pressing concern in previous decades has been the commercial trapping for fur, which reached its peak in the 1960s and 1970s. The fur trade initially targeted spotted and striped pelts from exotic breeds of Felidae, but international conservation has decreased the trade of these rare species. The California bobcat pelt is considered to be of mediocre quality, but it achieved prominence in the fur trade because it was the only spotted cat pelt sold legally (Jameson and Peters, 1988). Today, the fur trade relies on three species of lynx and the Chinese leopard cat (Prionailurus bengalensis), which is supplied by the USA, Canada, China and Russia (Grzimek, 2004). According to the State of California Department of Fish and Wildlife, the 2013 to 2014 Bobcat Harvest Assessment Report estimated that 1,639 bobcats were hunted during the license year (Department of Fish and Wildlife, 2014).

In the last four decades, human development has resulted in the depletion of prey species, creating a concern for conservation. The progress of human development has also caused habitat fragmentation of the California bobcat, resulting in an increase in disease incidence in the population. This fragmentation has directly caused a decrease in gene flow within the species, due to the avoidance of human developments; it has also caused an increase in pathogen transmission between previously isolated home ranges of individual bobcats (Lee et al., 2012).

There is little information documenting the dental pathology of wild animals, in particular that of wild felids. Dental lesions are common in the family Felidae, and can be a significant source of morbidity and mortality (Verstraete et al., 1996a, b). However, these lesions have yet to be meticulously classified in most wild felids. The aim of this study was to provide detailed information regarding the dental pathology of the California bobcat. It was hypothesized that dental lesions in wild felines may be similar to those found in domestic and feral cats, based on similarities or differences in disease susceptibility, behaviour and diet.

Materials and Methods
Macroscopic examination of 41 skull specimens from the Department of Ornithology and Mammalogy, California Academy of Sciences, San Francisco, and 236 skull specimens from the Museum of Vertebrate Zoology, University of California, Berkeley, was undertaken. Both collections of skulls were obtained from carcass recovery and donations from the public and other institutions.

Each skull had been previously labelled with a unique catalogue number, the collection date, collection location and sex of the animal (if known). Each
skull specimen was categorized as ‘young adult’ or ‘adult’. Age status of the skulls was determined based on the stage of development of the teeth, evaluated through dental radiography. ‘Juveniles’ were excluded from the study and identified through the presence of deciduous or mixed dentition.

The teeth and surrounding bony tissues were inspected systematically, according to predefined criteria (Table 1) utilized in previous studies (Verstraete et al., 1996a, b; Abbott and Verstraete, 2005). In order to verify and help classify certain lesions, dental radiographs were also obtained. The prevalence of dental lesions was compared between skulls from animals of different age (adult and young adult) and sex (male, female and unknown). Significance was calculated using the Pearson chi-square test and the Kruskal–Wallis test. Post-hoc comparisons of sex groups were performed using a Bonferroni–Holm method of multiple comparison adjustment of significance. \( P < 0.05 \) was considered significant.

The presence or absence (congenital, acquired or artefactual) of all teeth was recorded. Empty tooth alveoli, with sharply delineated edges were considered to reflect tooth loss during skull preparation and were noted as such. The number of teeth present was used to calculate the prevalence of attrition/abrasion, fractures, periodontitis, tooth resorption and endodontal disease. Teeth were assessed for normal or abnormal form through gross and radiographical examination. The number of roots was determined by assessing the visible part of the coronal root, with radiographical evaluation of the roots. The majority of teeth were glued into their alveoli during preparation. If the tooth could be removed, the roots were examined.

The presence of supernumerary teeth adjacent to normal teeth was recorded, as well as the presence of any persistent deciduous teeth. The teeth were examined for signs of attrition and/or abrasion (flattening of the tooth cusp or exposed dentine), although severity was not recorded. Any defects to the enamel were noted, particularly signs of enamel hypoplasia.

Tooth fractures were classified according to the World Health Organization classification of human dental fractures, as modified for use in carnivores (Verstraete, 2003). Periapical lesions communicating with the tooth in question were noted during the macroscopic examination and later examined radiographically. Teeth with periapical lesions resulting from complicated tooth fractures were examined radiographically for additional indications of endodontal disease, which can include external lesions, fractures, periodontitis, tooth resorption and endodontal disease.

### Table 1

<table>
<thead>
<tr>
<th>Observation</th>
<th>Criteria</th>
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<tbody>
<tr>
<td>Tooth artefactually absent</td>
<td>Jaw fragment missing or tooth absent, but a well-defined, sharp-edged, normally shaped, empty alveolus present; no pathological signs in the alveolar bone; tooth presumed lost during preparation or post-mortem manipulation of the skull.</td>
</tr>
<tr>
<td>Tooth absent (presumably acquired)</td>
<td>Tooth absent; alveolus or remnant alveolus visible; alveolar bone shows pathological signs (i.e. rounding of the alveolar margin, shallow alveolus, periosteal reaction on alveolar bone, increased vascular foramina).</td>
</tr>
<tr>
<td>Tooth absent (presumably congenital)</td>
<td>Tooth and alveolus absent; smooth, morphologically normal bone present at the site; no physical space for that tooth to have occupied.</td>
</tr>
<tr>
<td>Malformed tooth</td>
<td>Presence of an abnormally shaped crown, as in two fused teeth.</td>
</tr>
<tr>
<td>Number of roots</td>
<td>One, two or three roots.</td>
</tr>
<tr>
<td>Supernumerary tooth</td>
<td>Presence of a supernumerary tooth adjacent to an expected tooth (or alveolus).</td>
</tr>
<tr>
<td>Persistent deciduous tooth</td>
<td>A persistent deciduous tooth adjacent to an erupted or unerupted permanent tooth.</td>
</tr>
<tr>
<td>Attrition/abrasion</td>
<td>Rounding or flattening of the cusp tip; exposure of dentine, with or without tertiary dentine formation. A chip or fracture in the enamel only.</td>
</tr>
<tr>
<td>Enamel fracture</td>
<td>A fracture involving enamel and dentine, but not exposing the pulp.</td>
</tr>
<tr>
<td>Uncomplicated crown fracture</td>
<td>A fracture involving enamel, dentine and cementum, with pulp exposure.</td>
</tr>
<tr>
<td>Complicated crown fracture</td>
<td>A fracture involving enamel, dentine and cementum, but not exposing the pulp.</td>
</tr>
<tr>
<td>Uncomplicated crown-root fracture</td>
<td>A fracture involving enamel, dentine and cementum, with pulp exposure.</td>
</tr>
<tr>
<td>Complicated crown-root fracture</td>
<td>A fracture affecting dentine, cementum and the pulp.</td>
</tr>
<tr>
<td>Root fracture</td>
<td>Macrophotically visible periapical bone loss, root tip resorption, sinus tract formation originating periapically or obvious focal periosteal reaction overlying the apex.</td>
</tr>
<tr>
<td>Periodontitis stage 2</td>
<td>Evidence of increased vascularity at the alveolar margin (more prominent vascular foramina in, and slightly rougher texture of, the bone of the alveolar margin).</td>
</tr>
<tr>
<td>Periodontitis stage 3</td>
<td>Rounding of the alveolar margin; moderate horizontal or vertical bone loss.</td>
</tr>
<tr>
<td>Periodontitis stage 4</td>
<td>Widening of the periodontal space; severe horizontal or vertical bone loss; tooth mobile in the alveolus.</td>
</tr>
<tr>
<td>Enamel hypoplasia</td>
<td>Irregular pitting or a band-shaped absence or thinning of the enamel, consistent with the clinical signs of enamel hypoplasia.</td>
</tr>
</tbody>
</table>
inflammatory root resorption as well as failure of the pulp cavity to narrow.

The periodontal status of the teeth was assessed based on a well-established classification system developed for use with skull specimens (Verstraete et al., 1996a). In this classification system, periodontitis stages 2–4 were assigned based on bony lesions indicative of periodontitis. Stage 1 was excluded, as this refers to gingivitis, a soft tissue lesion that cannot be assessed on skull specimens.

Tooth resorption was noted and its extent classified according to predefined criteria (Table 2) established by the American Veterinary Dental College (American Veterinary Dental College, 2012). Tooth resorption was differentiated from external inflammatory root resorption by lack of an external inflammatory lesion in the periodontal ligament or tissues surrounding the teeth. Tooth resorption is characterized as osteoclastic destruction that results in replacement of the tooth roots by osteoclasts. Radiographically, the tooth appears to be less radiopaque and may have loss of the periodontal ligament space (Niemiec and DuPont, 2010). Stage 1 classification of tooth resorption was not included, as it is virtually impossible to determine this stage of tooth resorption grossly. Stage 4 classification of tooth resorption was not given a sub-classification during the radiographical examination. Stage 5 classification of tooth resorption was excluded during the gross examination, but was evaluated during the radiographical examination, due to the fact that radiographs are required to classify this stage of tooth resorption.

Any additional relevant observations were made, such as the presence of head trauma or gunshot wounds to the skull. The temporomandibular joint was also evaluated for signs of disease (Arzi et al., 2013). Any malocclusion or bony abnormalities were noted.

The second part of the study included obtaining dental radiographs of the teeth. A previously identified limitation to this type of study is that it is difficult to assess the tooth roots; this limitation was addressed with the addition of dental radiographs, in order to allow for more accurate diagnosis of dental lesions.

Radiographs were obtained using a portable handheld dental X-ray unit (Nomad Pro-Vet, Aribex, Charlotte, North Carolina, USA), intraoral phosphor storage plates sized 2 and 4 (ScanX, Air-Techniques, Melville, New York, USA) and diagnostic imaging software (Metron, EponaTech, Creston, California, USA). A standard ten maxillary and mandibular radiographical views were obtained for each skull specimen. These views included the left/right maxillary premolar—molar quadrants (extraoral near-parallel technique), the mandibular and maxillary incisor and canine occlusal views (bisecting angle technique), the left/right mandibular premolar—molar quadrants (parallel technique) and the left/right lateral maxillary and mandibular canine teeth (bisecting angle technique).

Once the radiographs were obtained, each radiograph was evaluated and compared with the findings of the gross examination. The presence or absence (i.e. congenital, acquired or artefactual loss) of all teeth was verified. The number of roots was confirmed radiographically for each tooth, together with any abnormal crown or root formation. Tooth fractures were confirmed and the classification of the fracture type was verified. Periodontitis was confirmed and the stage assigned was verified. Tooth resorption was evaluated and the stage assigned was confirmed. Endodontal disease (e.g. failure of the pulp cavity to narrow) and periapical disease, including external inflammatory root resorption (Peralta et al., 2010) were also documented.

**Results**

Of the 277 skull specimens, 46.2% were from male bobcats, 41.2% were from female bobcats and 12.6% were from animals of unknown sex. Adult bobcat skull specimens comprised 79.8% of the skulls examined, while young adult bobcat skull specimens comprised 20.2% of the skulls examined. A table listing the stages of tooth resorption and inclusion criteria is provided below:

<table>
<thead>
<tr>
<th>Observation</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td>Tooth resorption stage 2</td>
<td>Moderate dental hard tissue loss (i.e. cementum or cementum and enamel with loss of dentine that does not extend to the pulp cavity). Deep dental hard tissue loss (i.e. cementum or cementum and enamel with loss of dentine that extends to the pulp cavity); most of the tooth retains its integrity.</td>
</tr>
<tr>
<td>Tooth resorption stage 3</td>
<td>Extensive dental hard tissue loss (i.e. cementum or cementum and enamel with loss of dentine that extends to the pulp cavity); most of the tooth has lost its integrity.</td>
</tr>
<tr>
<td>Tooth resorption stage 4</td>
<td>Remnants of dental hard tissue are visible only as irregular radiopacities, and gingival covering is complete.</td>
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20.2% of the skulls examined. Fig. 2 illustrates the age and sex distribution of the skulls examined.

Presence of Teeth

The total number of teeth available for examination was 7,417 (95.6%), out of a potential total of 7,756 teeth. Artefactual tooth absence accounted for 74.9% of missing teeth (i.e. lost during skull preparation post mortem). Teeth lost through acquired means accounted for 20.4% of missing teeth (i.e. lost throughout the life of the animal). Congenitally absent teeth only accounted for 4.7% of missing teeth. Of the 16 congenitally absent teeth, 15 were found to be incisor teeth (on both the maxilla and the mandible) and one was found to be a mandibular third premolar tooth. The congenitally absent teeth were found in 11 specimens (4.0% of the population examined).

Adult bobcat specimens had more acquired tooth loss than young adult specimens ($P = 0.025$). The mandibular and maxillary incisor teeth accounted for a majority (84.1%) of teeth lost through acquired means. The mandibular first incisor tooth was the most commonly affected tooth.

Tooth Form

Abnormal tooth form was considered to be any irregular structure or formation of the crown of the tooth, root of the tooth, or both. This did not include teeth with an abnormal number of tooth roots, as these are evaluated in the following section.

The majority of teeth had normal morphology. Only 40 teeth with abnormal form were found (0.5% of teeth available for examination). Teeth with abnormal form were found in 25 skull specimens (9.0% of specimens examined). The most common abnormality in tooth form was unusually large crowns of the maxillary first molar teeth (11 teeth), with the right side being more commonly affected. The second most common abnormality in form was bigemination of the mandibular incisor teeth (nine teeth), with the mandibular second incisor tooth being most commonly affected (Fig. 3). The nine teeth with bigemination were identified in five individual specimens.
Dilaceration of tooth roots affected eight teeth. Six of these teeth were the maxillary incisor teeth of one specimen. Other less common form abnormalities were found. Three teeth were found to have abnormally small crowns (two incisor teeth and one maxillary molar tooth).

Seven teeth were found to have root abnormalities: a partially fused root, an extra root resulting in a malformed crown, two teeth with convergence of roots, two teeth with shortened distal roots and one abnormally large tooth root.

One adult specimen of unknown sex exhibited odontodysplasia of the left mandibular canine tooth (Fig. 4). This defect can be attributed to trauma during tooth development.

**Number of Roots**

Out of the teeth examined, only 68 (0.9% of teeth) were found to have an abnormal number of roots. These teeth were found in 46 individuals, 16.6% of the specimens examined. Out of the teeth with abnormal roots, 63 were maxillary first molar teeth seen with two roots instead of the expected one. This aberration of the maxillary first molar tooth was bilateral in 21 individuals (Fig. 5).

The five remaining teeth with abnormal roots had three roots, instead of the expected two roots; this included a left maxillary third premolar tooth (Fig. 6), a right mandibular third and fourth premolar tooth, a left mandibular third premolar tooth and a right mandibular first molar tooth.

**Supernumerary Teeth**

No supernumerary teeth were seen in any of the skull specimens examined.

**Persistent Deciduous Teeth**

Only three persistent deciduous teeth were noted in two skull specimens; all three were mandibular incisor teeth. One skull had two persistent deciduous mandibular first incisor teeth, while the other had a persistent deciduous left mandibular third incisor tooth.

**Enamel Hypoplasia**

There was no enamel hypoplasia in any of the skull specimens examined.

**Bony Changes Consistent with Periodontitis**

Periodontitis was assessed in 7.5% of teeth examined and seen in a majority of the population (56.0% of
specimens). Stage 2 periodontitis was found in 91.3% of teeth with periodontitis, stage 3 periodontitis was found in 6.9% of teeth with periodontitis and stage 4 periodontitis was rare (1.8% of teeth with periodontitis). In all cases of periodontitis, the most common teeth affected were the maxillary fourth premolar teeth and the mandibular first molar teeth (Fig. 7).

Adult bobcats were more likely to have periodontitis than young adults \((P < 0.001)\). Adult bobcats had more teeth with periodontitis than young adults \((P = 0.0003)\).

**Attrition/Abrasion**

Of the teeth examined, 24.1% exhibited attrition/abrasion. A majority (85.2%) of the specimens examined had some amount of attrition/abrasion. The incisor teeth accounted for 43.8% of teeth with attrition/abrasion, the molar teeth accounted for 21.5% and canine teeth accounted for 12.4% of teeth with attrition/abrasion. The two teeth that were most commonly afflicted with attrition/abrasion were the maxillary first molar tooth and the maxillary third incisor tooth.

Adult bobcats were more likely to have attrition/abrasion than young adults \((P = 0.047)\). Adult bobcats had more teeth with attrition/abrasion than young adults \((P = 0.0001)\). Male bobcats had more teeth with attrition/abrasion than females \((P = 0.0076)\).

**Tooth Fractures**

The total number of fractured teeth was 570 (7.7% of teeth) and the prevalence of specimens with any fracture type was found to be 50.9%. Severe tooth fractures (i.e. complicated crown-root, complicated crown and root fractures) accounted for only 3.6% of teeth examined, a much lower percentage than the total number of tooth fractures (7.7%).

Enamel fractures accounted for 155 (27.2%) of fractured teeth. Uncomplicated crown fractures accounted for 143 (25.1%) of fractured teeth. Complicated crown fractures accounted for 116 (20.4%) of fractured teeth; the most commonly afflicted teeth were the mandibular and maxillary canine teeth. Only two uncomplicated crown-root fractures (0.4% of fractured teeth) were seen. Complicated crown-root fractures accounted for 23 (4.0%) of fractured teeth. Root fractures accounted for 131 (23.0%) of fractured teeth; the most commonly afflicted teeth were the mandibular and maxillary first incisor teeth.

The most common fracture types were enamel fractures, followed by uncomplicated crown fractures and root fractures. Adult bobcats were more likely to have fractures than young adults \((P < 0.001)\). Adult bobcats had more fractured teeth than young adults \((P = 0.0001)\).
Endodontal Disease

Endodontal disease was assessed via dental radiography and recognized by the presence of a complicated tooth fracture with resulting periapical lesion, external inflammatory root resorption and/or a pulp cavity that failed to narrow.

Complicated tooth fractures (i.e. complicated crown-root, complicated crown and root fractures) were found to affect 270 teeth (3.6% of teeth) examined. Periapical lesions were subsequently diagnosed in 114 teeth (1.5% of teeth) examined. Teeth diagnosed with periapical lesions were found in 24.5% of specimens. The most commonly affected teeth were the mandibular and maxillary canine teeth, comprising 78.1% of teeth with periapical lesions (Fig. 8).

Adult bobcats were more likely to have periapical lesions than young adults ($P < 0.001$). Adult bobcats had more teeth with periapical lesions than young adults ($P = 0.0001$).

In addition to periapical lesions resulting from complicated tooth fractures, radiographs were also analyzed for the presence of other indicators of endodontal disease (i.e. external inflammatory root resorption and/or a pulp cavity that had failed to narrow). These additional radiographical features of endodontal disease were present in 109 teeth. The most common additional finding was external inflammatory root resorption, seen in a majority (58.7%) of teeth afflicted with additional radiographical signs of endodontal disease. The most frequently affected teeth were the mandibular and maxillary canine teeth. External inflammatory root resorption together with failure of the pulp cavity to narrow was seen in one specimen and affected the right maxillary canine tooth.

Adult bobcats were more likely to have additional radiographical signs of endodontal disease than young adults ($P < 0.001$). Adult bobcats had more teeth afflicted with additional radiographical signs of endodontal disease than young adults ($P = 0.0002$).

Tooth Resorption

Tooth resorption was found in 73 teeth (1.0% of teeth examined), in 9.4% of specimens. Stage 2 tooth resorption was found to affect 32 teeth (43.8% of teeth with resorption), stage 3 tooth resorption affected 20 teeth (27.4% of teeth with resorption), stage 4 tooth resorption affected 13 teeth (17.8% of teeth with resorption) and stage 5 tooth resorption affected eight teeth (11.0% of teeth with resorption).

Stage 2 tooth resorption affected mostly the mandibular and maxillary premolar teeth, affecting inflammatory root resorption was seen in one specimen and affected the right maxillary canine tooth.
half of teeth with this resorption type (Fig. 9). Stage 3 tooth resorption affected mostly the mandibular and maxillary premolar teeth (60.0% of teeth with stage 3 tooth resorption) (Fig. 10). Stage 4 tooth resorption had a relatively even spread, affecting the premolar and incisor teeth most commonly. Stage 5 tooth resorption almost exclusively affected the maxillary incisor teeth, with the exception of one mandibular incisor tooth.

Adult bobcats were more likely to have tooth resorption than young adults ($P = 0.007$). Adult bobcats had more teeth with tooth resorption than young adults ($P = 0.0072$).

### Head Trauma and Gunshot Wounds

During gross examination, each skull was assigned a status of ‘head trauma’, ‘gunshot wound’, ‘shattered’ or ‘intact’. Of the 277 skull specimens, the majority (66.4%) were intact, 17.7% of the specimens had sustained head trauma, 15.5% of the specimens had gunshot wounds and only one skull was shattered. Out of the specimens that had sustained head trauma, the majority (79.6%) of the specimens were from adult bobcats. Out of the specimens that had gunshot wounds, the majority (81.4%) were from adult bobcats.

### Other Findings

One adult female specimen had severe malocclusion of the right maxillary and mandibular canine teeth, presumably due to trauma during development (Fig. 11).

### Discussion

The California Academy of Sciences, San Francisco, and the Museum of Vertebrate Zoology, University of California, Berkeley, house a high quality collection of California bobcat skulls. The collection dates of the skulls ranged from 1894 to 2011 and were obtained from carcass recovery, donations from the
Congenital and developmental lesions were uncommon in this sample of California bobcats. Congenitally absent teeth were rare; only 16 cases were seen. In two studies of the anatomical variation in the dentition of domestic cats (Verstraete and Terpak, 1997) and feral cats (Verstraete et al., 1996a), the most frequent congenitally absent teeth were the maxillary second premolar tooth followed by the maxillary first molar tooth. The present study differs due to the fact that the bobcat has already lost the maxillary second premolar tooth during evolution. In this population of California bobcats, the most common congenitally absent teeth were the mandibular and maxillary incisor teeth.

Abnormal tooth morphology was also rare, with only 40 teeth found to have an abnormal form (0.5% of teeth). The most common morphological abnormality was unusually large crowns of the maxillary first molar tooth, with a right-sided predilection. The second most common form abnormality was bivemination of the mandibular incisor teeth, most commonly affecting the second incisor tooth.

Enamel hypoplasia was not identified in any of the specimens examined. In a previous study of the dentition of feral cats, enamel hypoplasia was identified at a prevalence of 24.6% (Verstraete et al., 1996a). Viral diseases (specifically morbillivirus infections) are known to cause disease resulting in enamel hypoplasia in man and in the dog; however, the rare feline paramyxovirus encephalomyelitis can be associated with similar disease in cats (Verstraete et al., 1996a).

An abnormal number of tooth roots was more common (0.9% of teeth) than teeth with abnormal morphology. Teeth with an abnormal number of roots were seen in 16.6% of the skulls studied. The majority (92.6%) of teeth with abnormal roots were maxillary first molar teeth seen with two roots instead of one. This was bilateral in fewer than half (45.7%) of specimens with this type of root abnormality. There was only one specimen with a maxillary third premolar tooth with three roots, instead of the expected two.

In two previous studies of dentition in domestic (Verstraete and Terpak, 1997) and feral cats (Verstraete et al., 1996a), three-rooted maxillary third premolar teeth were identified at a prevalence of 10.3%. This specific variation in root number was not seen in the California bobcat.

The three most common dental lesions in the California bobcat (considering both prevalence and percentage of teeth affected) were periodontitis, attrition/abrasion and tooth fractures. These lesions correlate to common dental lesions seen in other members of the family Felidae. The diagnosis of periodontal lesions from dry skulls is fundamentally flawed due to the lack of soft tissue, which is essential for diagnosis. However, the hyperaemia associated with inflammation is revealed in hard tissues by increased vascular foramina, a rough texture of the alveolar process and bone loss (Verstraete et al., 1996b). Periodontitis was the second most common dental lesion in this study, affecting 56.0% of specimens and 7.5% of teeth. Stage 2 periodontitis was diagnosed most often in this population of bobcats. The teeth most commonly affected with periodontitis were the maxillary fourth premolar tooth and the mandibular first molar tooth. In a previous study of the dentition and associated pathology in a group of feral cats, periodontitis was found to affect 48.0% of the population and 8.3% of teeth (Verstraete et al., 1996b). The California bobcat had a higher prevalence of periodontitis, with a lower percentage of teeth affected when compared with this population of feral cats. Periodontitis is an important cause of tooth loss in cats. In addition to tooth loss, severe bone loss can result in pulpite, pulp necrosis and endodontic disease (Lommer and Verstraete, 2001). The long-term impact of periodontitis can have severe consequences on the functionality and integrity of a cat’s dentition, especially for cats that depend on their teeth in order to hunt and consume prey.

‘Attrition’ refers to the physiological wear of teeth as they move against one another or food during mastication, affecting the occlusal surfaces most commonly. ‘Abrasion’ is defined as pathological wear due to an abnormal mechanical process (Shafer et al., 1983). Attrition and abrasion were grouped for the purposes of this study due to the fact that assigning either process to a tooth would be speculative. Attrition/abrasion was the most common dental lesion encountered in this study, affecting a majority of the specimens examined (85.2%) and 24.1% of teeth. The three teeth most commonly affected with attrition/abrasion were the incisor teeth, molar teeth and canine teeth. This distribution of tooth wear suggests that the bobcat, like larger
members of the family Felidae, uses its incisor and canine teeth together with its molar teeth in order to remove meat from its prey (Grzimek, 2004).

Tooth fractures were the third most common dental lesion seen in this study, affecting 50.9% of specimens and 7.7% of teeth. Tooth fractures of all six types were noted. However, severe tooth fractures (i.e. complicated crown, complicated crown-root and root fractures) only accounted for 3.6% of teeth examined. In a study of feral cats, dental fractures were noted at a slightly higher rate in the population (54.8%), affecting a lower percentage of teeth (7.0%); the majority of fractures were complicated crown fractures and root fractures (Verstraete et al., 1996a). The California bobcat differs from feral cats in that the two most common types of tooth fractures were enamel fractures and uncomplicated crown fractures.

Endodontal and periapical disease, including external inflammatory tooth resorption, was also diagnosed in the California bobcat, but at a lower prevalence than the types of dental pathology listed above. Periapical lesions typically result from pulp exposure and subsequent pulp necrosis. Periapical rarefaction is seen radiographically and is a lucency of the periapical bone, caused by loss of mineralization of the alveolar bone (Lemmons, 2013). Inflammation of the periapical tissues can result in lesions of varying intensity and chronicity as a result (Lommer and Verstraete, 2000). In the present study, periapical disease was seen in 24.5% of specimens and found to affect 114 teeth (1.5% of teeth). Dental radiographs improved the diagnosis of smaller and more subtle lesions. In the California bobcat, the mandibular and maxillary canine teeth comprised a majority (78.1%) of teeth with periapical disease. In a study of feral cats, the mandibular and maxillary canine teeth were also the most common teeth to be affected with periapical disease (Verstraete et al., 1996a). Periapical lucencies are commonly associated with fractured teeth and severe periodontitis (Lommer and Verstraete, 2000). In the present study, the periapical lucencies in the canine teeth were most commonly due to complicated crown fractures that were obtained via traumatic means throughout the life of the animal.

Additional signs of endodontal disease were diagnosed on radiographs. This included having a pulp cavity with failure to narrow and/or external inflammatory root resorption. The width of the pulp cavity was assessed by comparing contralateral teeth. A healthy tooth will age and continue to deposit secondary dentine, thickening the dentine layer and in turn narrowing the pulp cavity (Lemmons, 2013). A tooth with a pulp cavity that is wider than its counterpart is assumed to have stopped maturation due to pulp death. External inflammatory root resorption can lead to the blunted appearance of the apex of the root; this process can be severe enough to result in a noticeably shortened root tip (Lemmons, 2013). In the present study, additional radiographical signs of endodontal disease were found in 109 teeth (out of the 114 teeth with complicated tooth fractures and resulting periapical lesions). In the California bobcat, all of the teeth diagnosed with external inflammatory root resorption together with a pulp cavity that had failed to narrow were mandibular and maxillary canine teeth. Complicated crown fractures of the canine teeth of the California bobcat have potentially severe consequences, resulting in endodontal and periapical disease.

Tooth resorption is of interest in the family Felidae, especially in wild felines such as the California bobcat. One aim of the present study was to accurately diagnose and document the prevalence of tooth resorption in this population of wild cats, since data are lacking in this area. This was accomplished through use of dental radiography, which allows for a more accurate and thorough diagnosis of lesions than through gross examination alone. In a study examining the diagnostic value of full-mouth dental radiographs in domestic cats, dental radiographs yielded additional clinically relevant information in 41.7% of cats that was not detected on examination alone, and in 98.4% of domestic cats that had already been clinically diagnosed with tooth resorption (Verstraete et al., 1998). In the population of bobcats studied, tooth resorption was found in 9.4% of specimens, affecting <1.0% of teeth examined. In the study of feral cats, tooth resorption was seen at a higher prevalence in the population (14.3%) and affected a higher percentage (1.2%) of teeth (Verstraete et al., 1996b). In domestic cats, there are less available data on prevalence in the general population; however, it has been estimated that tooth resorption affects 20% to 67% of domestic cats (Lemmons, 2013).

Tooth resorption in felines is known to be a progressive resorption of the dental hard tissues by osteoclasts (odontoclasts), although the exact aetiology is still unknown (Lemmons, 2013). Many factors have been considered as potential causes for the initiation of tooth resorption; however, no definitive answers exist. The present study adds to the body of evidence showing that tooth resorption is not a disease of domestication, but in fact a common disease of felines. Tooth resorption is a painful process as it progresses in severity (Lemmons, 2013). It can be inferred that when in advanced stages, tooth resorption and other dental diseases have a negative impact on the welfare and survival of affected bobcats.
In conclusion, the California bobcat was found to exhibit a range of dental lesions and abnormalities. The prevalence of congenital and developmental abnormalities was relatively low, but acquired lesions were common, especially attrition/abrasion, periodontitis and tooth fractures. Acquired lesions affected adult bobcats more frequently and severely than young adults. As a result of acquired lesions, some specimens suffered from endodontal and periapical disease. It was of particular interest to show that tooth resorption is found in the California bobcat, although at a lower prevalence than in some other members of the family Felidae. Specimens that exhibited severe generalized dental disease would have likely suffered from considerable morbidity while alive, possibly leading to an increase in mortality.

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