Research in Veterinary Science 107 (2016) 213–219

Contents lists available at ScienceDirect

Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Oral health correlates of captivity

Varsha Kapoor [a], Tyler Antonelli [b], Jennifer A. Parkinson [c], Adam Hartstone-Rose [b,d,*]

[a] Medical University of South Carolina School of Dental Medicine, United States
[b] Department of Cell Biology and Anatomy, University of South Carolina School of Medicine, United States
[c] Department of Anthropology, University of San Diego, United States
[d] Animal Collections and Conservation, Riverbanks Zoo and Garden, United States

ARTICLE INFO

Article history:
Received 13 October 2015
Received in revised form 18 April 2016
Accepted 17 June 2016

Keywords:
Panthera
P. leo
P. tigris
Gingivitis
Gum disease
Caries

ABSTRACT

The predominant diet fed to captive carnivores in North America consists of ground meat formulated to provide full nutritional requirements. However, this ground meat diet completely lacks the mechanical properties (i.e., toughness and hardness) of the foods these animals would consume in the wild. The goal of this study is to evaluate the effect of captivity on oral health by comparing the prevalence of periodontal disease and dental calculus accumulation in wild and captive lions and tigers (*Panthera leo* and *Panthera tigris*), and to also correlate oral health with cranial morphology in these specimens. To achieve this, 34 adult lion and 29 adult tiger skulls were scored for the presence and extent of dental calculus and periodontal disease. These oral health scores were also compared to cranial deformations examined in a previous study. We found that the occurrence and severity of calculus buildup and periodontal disease was significantly higher in captive felids compared to their wild counterparts. Further, higher calculus accumulation occurred on the posterior teeth when compared to the anterior teeth, while an opposite trend for periodontal disease was observed. We also found a significant correlation between oral health and cranial morphology of lions and tigers. The results suggest that food mechanical properties are significant factors contributing to oral health in felids.

1. Introduction

The composition of the diet of captive carnivores is of great interest to animal curators, keepers and veterinarians. However, this interest has focused almost entirely on the nutritional composition of the diet (e.g., Whitehouse-Tedd et al., 2015) and little consideration has been given to the mechanical properties of foods such as toughness and hardness. While the incorporation of bones as dietary supplements or as enrichment is a growing trend (McPhee, 2002; Skibiel et al., 2007), the predominant diet fed to captive carnivores in North America consists of ground meat (Bechert et al., 2002; Kerr et al., 2013). While ground meat diets may contain all of the nutrients found in a natural diet, they does not simulate the ingestive or masticatory challenges that wild carnivores face (Haberstroh et al., 1984). In particular, the lack of bone and connective tissue in the captive diet may lead to dental health issues (Haberstroh et al., 1984; Lindburg, 1988). Numerous studies in domestic animals have demonstrated that mechanical attributes of the diet appear to affect dental calculus buildup and oral health in general (Antonelli et al., 2015; Logan, 2006; Vosburgh et al., 1982; Watson, 1994). However, thorough examination of the way in which the mechanical properties of foods affect oral health in large felids remains to be carried out. This study focuses on the correlation between dental health and captivity status in captive felids.

2. Background

2.1. Experimental Studies

The mechanical properties of food have long been thought to affect the oral health of domestic dogs and cats as well as captive exotic carnivores (Fagan, 1980). Several studies have noted the correlation of soft diets with excessive calculus accumulation, gingivitis, and periodontal disease in dogs and cats (Logan, 2006; Watson, 1994) and exotic carnivores (Fagan, 1980). It is thought that a dry diet is associated with less gingival pathology because the abrasive action of dry/rough foods against the gingivae in effect acts as a toothbrush, cleaning the teeth and removing food particles trapped in the gingival sulcus (Haberstroh et al., 1984; Vosburgh et al., 1982).

Numerous studies have supported the hypothesis that mechanical properties of the diet are significant factors in the oral health of captive carnivores. A study conducted on captive wolves (*Canis lupus*) found that animals fed a hard, dry diet exhibited significantly lower levels of

* Corresponding author at: Department of Cell Biology and Anatomy, University of South Carolina School of Medicine, United States.
E-mail address: AdamHR@sc.edu (A. Hartstone-Rose).

http://dx.doi.org/10.1016/j.rvsc.2016.06.009
0034-5288/

Table 1
Number of specimens in this sample broken down by species, captivity status, and sex (n = 63).

Common Name	Species	Captive (Zoo)	Wild	Male	Female
Lion	*Panthera leo*	15	19	17	17
Tiger	*Panthera tigris*	20	9	14	15
	TOTAL	35	28	31	32

plaque accumulation after four months than those fed a soft, meat-based diet (Vosburgh et al., 1982). A study of captive Amur Tigers (*Panthera tigris altaica*) found that when animals being fed a diet of commercially produced soft meat had their diets supplemented at least twice per week with beef bones (with muscle and connective tissue still attached) they showed lower incidence of gingivitis and periodontal disease (Haberstroh et al., 1984). Several studies of domestic beagles (*Canis lupus familiaris*) have also found that those fed abrasive diets including commercial dry foods or biscuits showed lower rates of periodontal disease and tartar accumulation than those on soft diets (Brown and Park, 1968; Samuelson and Cutter, 1991; Watson, 1994). Another study showed that ferrets (*Mustela putorius furo*) fed a soft diet of bread and milk developed periodontal disease within 8–12 weeks. The addition of bones to their diet prevented periodontal disease and even caused a decrease in calculus accumulation (Verstraete, 2003).

2.2. Felid Dental Anatomy and Function

As in all mammals, carnivorans have four types of teeth: incisors, canines, premolars and molars. In most carnivores the incisors are used for grasping and tearing, though they are relatively vestigial in modern felids. Felid canines are used for capturing and killing prey, and the premolars and carnassials are used primarily for slicing flesh. Felids have no functional dental region distal to their carnassials – a molar region that many other carnivorans use for grinding tougher foods (Hartstone-Rose, 2008; Hartstone-Rose et al., 2012; Logan, 2006; Van Valkenburgh, 1989).

A typical adult felid has a total of 30 teeths with the following dental formula: I3/3, C1/1, P3/2, M1/1, where I, C, P and M represent Incisors, Canines, Premolars and Molars respectively, and the number on either side of the "/" signifies the number of teeth of that kind in each upper and lower quadrant respectively (Wiggs and Bloom, 2003). Teeth are anchored into the alveolar bone by the periodontal ligament. In healthy animals, gingival tissue covers the alveolar bone and tooth root to a level just below the area where enamel meets the root surface (Niemiec, 2008a).

2.3. Dental Calculus and Periodontal Disease

Dental calculus, or tartar, can be defined as calcified or calcifying deposits of dental plaque (a microbial biofilm) attached to the enamel surface (Busscher et al., 2004). Calculus is primarily composed of inorganic compounds consisting of crystalline salts, but it is usually covered by an active layer of bacterial plaque. New calculus is formed as this active layer of bacterial plaque mineralizes (Deinzer et al., 2005; Marcenes and Sheiham, 1992). When plaque and calculus spread under the gingival line, it causes irritation leading to an inflammatory condition of the soft tissue known as gingivitis (Campbell, 2006). As calculus builds under the gingiva, the bacteria in the sub-gingival plaque set in motion a cycle of damage to the supporting tissues around the tooth, and a more severe form of periodontal disease known as periodontitis may develop (Pihlstrom et al., 2005). Periodontitis can lead to bone loss, tissue destruction, and ultimately tooth loss (Campbell, 2006).

Periodontal disease is the most prevalent disease in domestic carnivores and has been found in approximately 80% of adult dogs in one study (Niemiec, 2008b). It is less common in wild carnivores (Wiggs and Bloom, 2003), possibly due to differences in the food consistency of wild and captive carnivores.

2.4. Captive Felid Diet

The most common diet provided to felids in captivity in North America consists almost entirely of commercially prepared meat supplemented with vitamins (Vester et al., 2008). While this ground meat diet attempts to ensure that an animals' nutritional needs are met (Kerr et al., 2013), it lacks the mechanical properties of the natural felid diet which consists of intact prey animal carcasses. In the wild, large felids consume flesh straight from the bone. In doing so, they

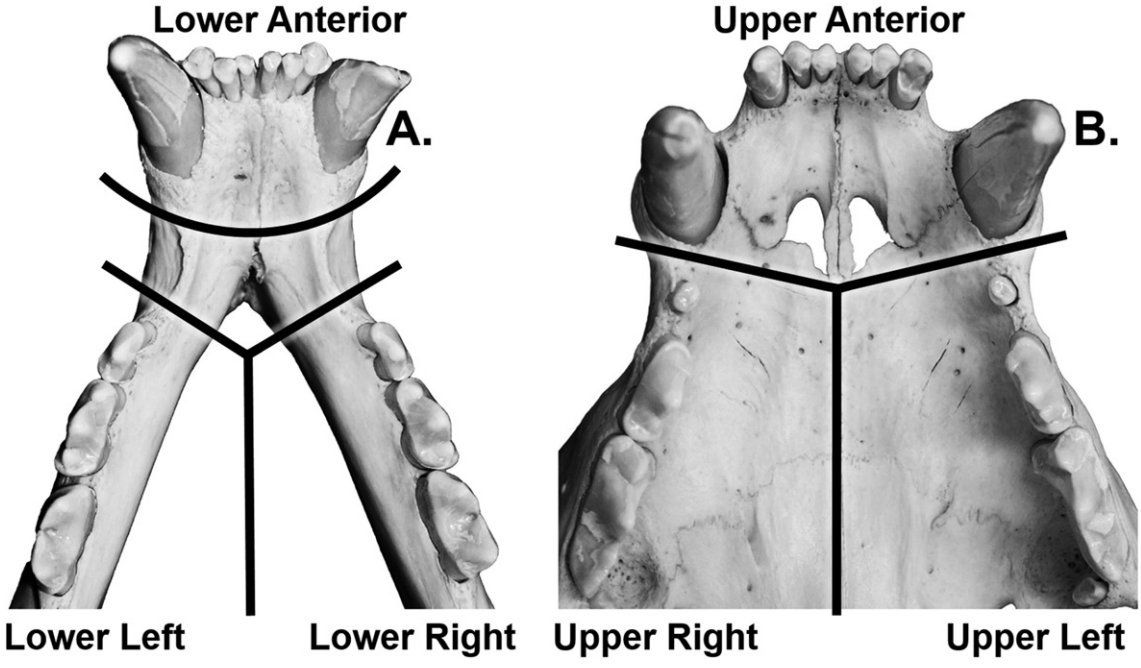

Fig. 1. Analytical sections for the mandibular (A.) and maxillary (right) teeth.