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Cover Page Footnote

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A Study of Dental Pathology in River Otters (*Lontra canadensis*) in Arkansas

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Running Title: Dental Pathology in Arkansas Otters

Abstract

River otters (*Lontra canadensis*) consume a variety of foods, including mussels, fishes, and crayfishes. These foods have hard body parts that cause wear of the teeth as the predator ages and incurs more damaging feeding experiences. This can lead to exposure of the pulp cavity and possible abscess and resorption of bone around the alveolus. Further, strong bites against harder parts of prey sometimes results in mechanical breakage, which can lead to pulpitis and severe pathology leading to tooth loss. We investigated the frequency of different forms of dental issues in a sample of 178 skulls of river otters collected from Arkansas. Canines and carnassial teeth, most used in capture and mastication of prey, were most severely affected. Based on post-traumatic tooth wear, it is evident that some otters are able to survive severe dental disease.

Introduction

The North American river otter (*Lontra canadensis*) is a semi-aquatic mustelid that inhabits watercourses throughout much of North America, although its historic range has been decreased by human activity. Range wide, its primary foods are fishes, crayfishes, and amphibians (Larivière and Walton 1998), which is true also in Arkansas (Tumlison *et al*. 1986, Tumlison and Karnes 1987). Among mustelids, the bite force of river otters is moderately strong, and is most powerful at the carnassials (P^4/M_1), being adapted to a largely piscivorous diet (Christiansen and Wroe 2007, Timm 2013). Diet seems to be the primary factor affecting rates of tooth fracture in carnivorans, with species that consume foods with harder parts having the highest rate of dental damage (Van Valkenburgh 2009). In otters, tooth wear is most prominent in populations that feed heavily on shellfishes (Spelman 1998). Zoo studies (Duplaix-Hall 1975) and studies of otters released in reintroduction efforts (Hoover *et al*. 1984) found dental pathology to be common in live river otters.

A damaged canine might significantly affect the ability of a predatory mammal to capture and kill prey, and loss of carnassial function (the primary meat-processing teeth) decreases the ability to shear meat and consume sufficient food. Dental pathology could lead to secondary infections and death (Barber-Meyer 2012), or at least affect reproductive success in a weakened animal. However, about 25% of large predatory carnivores tend to have at least 1 broken tooth, and damage is greatest in canines, followed by premolars, carnassials, and incisors (Van Valkenburgh 1988). Further, 40% of mustelids had breakage of at least 1 tooth (Van Valkenburgh 2009).

Damage leading to pulp cavity exposure has been reported in most kinds of teeth of otters in Arkansas (Tumlison *et al*. 1989). The present study was conducted to determine the kinds, frequency, and severity of dental pathologies in otters from Arkansas, and to look for patterns of pathology in teeth serving different functions.

Methods and Materials

We examined 178 cleaned skulls (97 males, 80 females, 1 unknown sex) of river otters collected from counties scattered over Arkansas, and preserved in the Henderson State University collection of mammals. All teeth (Figure 1) as well as the surrounding alveolus and bone, were examined for any damage or pathology. Protocol was similar to that of Janssens *et al*. (2016). We documented the following kinds of issues when present in the sample of dentitions: attrition (AT) – normal wear due to biting and gnawing, which increases with age and tends to be spread over most teeth; abrasion (AB) – caused by gnawing or biting hard structures such as bones, so damage may be limited to a few teeth; enamel fracture (EF) – only the enamel is broken, exposing the dentine; pulp exposure (P) – the pulp cavity is exposed which can result in infection called pulpitis; periodontal disease (PD) – infection has occurred and osteomyelitis (bone resorption) and abscess may be detected. We also noted hypodontia (MT) – missing teeth not caused by fracture while in traps, and hyperdontia (supernumerary teeth).

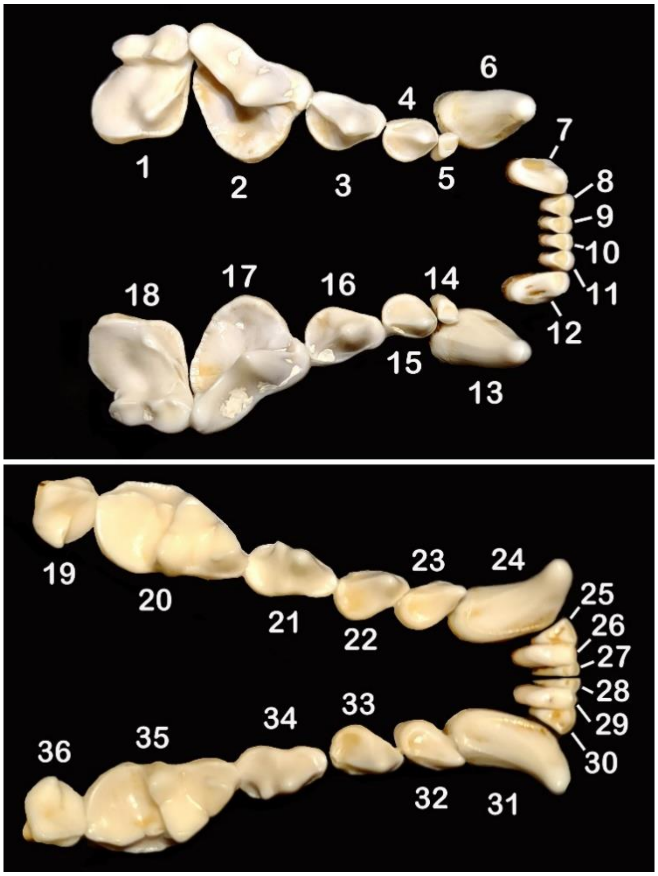

Figure 1. Teeth of the river otter (*Lontra canadensis*) in nearly perfect condition. Upper image is upper dentition and lower image is of teeth in the lower jaw. Numbers indicate individual teeth in the total complement of 36. In the following, names for teeth (also see Table 1) are symbolized as L=left, R=right, I=incisor, C=canine, P=premolar, and M=molar. The last digit represents the technical tooth number, and a superscript indicates upper teeth and subscript is for lower teeth. 1=RM^1, 2=RP^4, 3=RP^3, 4=RP^2, 5=RP^1, 6=RC^1, 7=RI^3, 8=RI^2, 9=RI^1, 10=LI^1, 11=LI^2, 12=LI^3, 13=LC^1 14=LP^1, 15=LP^2, 16=LP^3, 17=LP^4, 18=LM^1, 19=LM$_2$, 20=LM$_1$, 21=LP$_4$, 22=LP$_3$, 23=LP$_2$, (there is no lower P$_1$ in otters) 24=LC$_1$, 25=LI$_3$, 26=LI$_2$, 27=LI$_1$, 28=RI$_1$, 29=RI$_2$, 30=RI$_3$, 31=RC$_1$, 32=RP$_2$, 33=RP$_3$, 34=RP$_4$, 35=RM$_1$, 36=RM$_2$.

Trapped otters sometimes damage their teeth, especially canines and incisors, by biting the metal of traps, though the extent of damage usually is not considered to be a threat to survival (Serfass *et al*. 1993). To avoid biases from recent damage, we did not include broken teeth in our study if the edges were still sharp. However, smoothed edges indicate that breaks were old, so these were included in analysis. We compiled observations into a table to allow investigation of patterns of tooth pathology.

Results and Discussion

Frequencies of dental pathology differed among different types of teeth (Table 1, also see Figure 2). Predictably, teeth from younger specimens tended to show less wear and other damage than did teeth of older specimens, and older otters tend to present the most severe pathologies. Though the frequencies expressed in the table do not account for age or sex, they do represent overall patterns of issues and show which sets of teeth are most affected compared to other teeth.

Attrition. – One form of attrition is the smoothing of the surfaces of the teeth, but another results when the pressures of mastication cause exposures of tooth roots, called alveolar thinning. This is a common form of attrition (Beaver *et al*. 1981).

Most deviations from the perfect dentition were due to normal wear, which was observed in all teeth and appeared most on older specimens. Of the incisors, those located next to the canines were most affected by attrition. Canines are the first points of contact for an otter bite, and their expected high rates of attrition were exceeded only by rates for the pairing of M^1/M$_1$. The anterior part of the lower tooth in this occluding pair provides shearing function, but the posterior half is broader and more flat, similar to most of the upper tooth, and is used primarily for crushing and grinding (Riley 1985). The carnassial pair (P^4/M$_1$) also had high rates of attrition, but less than M^1/M$_1$. It appears that the bone-crushing attributes of M^1/M$_1$ result in greater rates of attrition, whereas the meat-shearing function of the carnassials is exposed to relatively lesser stresses. The premolars nearest the canines generally were least affected by attrition, as the more anterior premolars are smaller and less exposed to pressures of food handling and mastication.

Abrasion. – A more localized and intense form of wear, abrasion was most pronounced on all the canine teeth. Otters have elongated heads with long mandibles, which places the bite point farther from the temporal-mandibular joint and creates high-velocity jaws suited for capture of fast-swimming fishes (Timm 2013). The first and primary point of contact in prey capture is the canines, which endure the escape struggles of captured prey such as fishes. The high coronoid process of the dentary is pulled by the temporalis muscle to cause greatest force on the canines (Timm 2013) to allow the otter to hold the prey. This likely results in higher levels of wear at these points of contact.

Enamel fracture. – The pressure exerted by the temporalis muscle to hold against the struggles of prey to escape apparently also increases the chances of

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breaking enamel. Canines were the most involved teeth in this level of pathology.

Table 1. Frequencies of tooth damage expressed as percentages based on 178 specimens of river otter dentitions from Arkansas. One specimen = a frequency of 0.56%. Tooth numbers and identities as in Figure 1. Columns (AT=attrition, AB=abrasion, EF=enamel fracture, P=pulp exposure, PD=periodontal disease, and MT=missing teeth) arranged from least (left) to greatest (right) damage.

Tooth	AT	AB	EF	P	PD	MT
1=RM^1	23.03	0	0.56	1.12	0.56	0.56
2=RP^4	15.2	0	0	9.36	1.69	0
3=RP^3	14.04	2.25	0	9.55	1.12	1.12
4=RP^2	11.8	0.56	0.56	5.62	0.56	0.56
5=RP^1	0.56	0	0.56	2.81	0	4.49
6=RC^1	20.7	8.99	4.49	17.42	0	0.56
7=RI^3	6.18	0.56	0	3.93	0	0
8=RI^2	1.12	0	0	1.69	0	2.25
9=RI^1	3.37	1.12	0	2.25	0	0.56
10=LI^1	2.81	0	0	1.69	0	0
11=LI^2	1.69	0	0	1.12	0	0
12=LI^3	6.18	1.69	1.12	2.81	0	0
13=LC^1	18.54	5.62	3.37	16.85	0	0.56
14=LP^1	2.25	0.56	0	2.25	0	3.37
15=LP^2	12.36	0	0	3.37	0	0.56
16=LP^3	11.24	0.56	1.12	10.11	0	0.56
17=LP^4	16.29	0.56	0	6.18	0.56	0
18=LM^1	23.03	0	0	1.69	0.56	0
19=LM_2	3.93	0	0	0	0.56	0
20=LM_1	22.47	0	0	3.93	4.49	0
21=LP_4	15.17	0	1.12	7.87	1.69	0
22=LP_3	12.92	0	0	5.62	1.69	1.69
23=LP_2	6.74	0.56	0	5.62	0.56	1.69
24=LC_1	15.17	6.18	5.06	12.36	0.56	0
25=LI_3	11.8	0.56	0.56	1.12	0	0
26=LI_2	10.11	0	0	0.56	0	0.56
27=LI_1	4.49	0	0	0	0	1.69
28=RI_1	3.37	0	0	0	0	3.37
29=RI_2	9.55	0	0	1.69	0	0
30=RI_3	11.24	0.56	0	1.69	0.56	0.56
31=RC_1	15.73	6.74	5.06	11.24	0	0
32=RP_2	10.67	0.56	0.56	3.93	0.56	0.56
33=RP_3	15.73	0	0	5.06	0.56	1.12
34=RP_4	12.36	0	0	7.3	2.24	0.56
35=RM_1	19.1	0	0.56	4.49	4.49	0.56
36=RM_2	3.37	0	0	0	0	0.56

***Pulp exposure*. –** Canines again suffered the highest chances of damage and were about twice as likely as cheek teeth (the next most damaged teeth) to have exposed pulp cavities. This is likely due to the precursory effects of attrition, abrasion, and enamel fracture on canines as the animal ages. Similar results were reported by Tumlison *et al*. (1989). Incisors seldom suffered exposures, but when present they seemed to result from attrition on older specimens. Molars also showed relatively few examples of exposure, likely due to their low cusps and broad construction. However, premolars, especially those involved in or nearest the carnassial dentition presented several exposures. Increased damage to these teeth results from the pressure produced by the masseter muscle to create bone crushing and flesh slicing action (Herring *et al*. 2001), which also made those premolar and molar teeth exhibit higher attrition. Force generated by the masseter is maximized on these teeth due to their position in the posterior one third of the jaw (Greaves 1982).

***Periodontal disease*. –** Osteomyelitis (bone infection) may have been present in some otters that could not be detected in their prepared skulls. Infection can cause bone resorption and produce a porous appearance in the area of the infection, and more severe disease (abscess) may create larger holes (fistulas) in the bone. In our sample of otter skulls, these indicators were most common around the lower first molars (the lower part of the carnassial pair), which is the area producing the greatest pressures for handling of food. Although it is not known to what extent mortality of otters may be caused by oral pathology, it is evident that some are able to survive. One specimen in our sample had severely broken P^4s, with only the roots remaining of much of the teeth (see Figure 2H), yet those roots had been polished by wear. This indicated that the otter had lived quite some time after the dental issues had developed. Otters with only 1 or 2 teeth have survived translocation and have been tracked for up to 2 yr postrelease with radio telemetry (Kimber and Kollias II 2000).

Also of note, the canines can suffer serious exposures of the pulp cavity, but in our sample they did not show indications of bone disease, and incisors also rarely presented bone damage.

***Missing and extra teeth*.** – We noted some broken or missing teeth that were not included in our analysis because the fractures were jagged and could have been caused by trap biting. Teeth missing from an unaltered and complete alveolus were not counted, because these likely represented teeth that fell out during the skull cleaning processes. If the alveolus was visible but had been partially filled by bone, the tooth had been lost earlier in the life of the otter and was counted. In other cases, there might have been congenital loss, in which the teeth never formed, leaving a gap but normal bone where the tooth should be. Missing teeth most often were smaller teeth including anterior premolars and the smaller of the incisors (Figure 2EFG). Severe periodontal disease was believed to have caused loss of 1 upper molar, due to bone filling of the vacated alveolus and the porous nature of the surrounding bone.

Additional teeth (supernumerary) have been reported in otter (Beaver *et al*. 1982, Tumlison *et al*. 1985), but none was encountered in our sample.

Conclusions. – Attrition progresses with age, sometimes causing pulp cavity exposures and progressive disease. Damage to teeth occurred most frequently, and most severely, where muscles put the most pressure at contact points. Canines pulled tight against prey by the temporalis muscles acting on the very high coronoid process of the dentary were commonly affected. Masseteric force against the carnassial (P^4/M_1) also disposed that area to greater wear, breakage, and osteomyelitis than found on other teeth.

Still, in spite of severe dental issues, smoothness of some broken teeth due to attrition revealed that some otters survive with significant oral pathologies. For example, a male specimen from Prairie Co. (HSU 713) suffered pulp exposures on 19 of its 36 teeth, and some of those teeth were worn to the mandible, but no signs of periodontal or bone disease were detectable. In several other older specimens, broken teeth, missing teeth, and osteomyelitis indicated severe issues. Because the specimens included in this study were collected as full carcasses from fur buyers and trappers, we were able to observe that there were no emaciated individuals in the sample. This indicates that those otters were able to procure adequate food in spite of the oral diseases we later evaluated.

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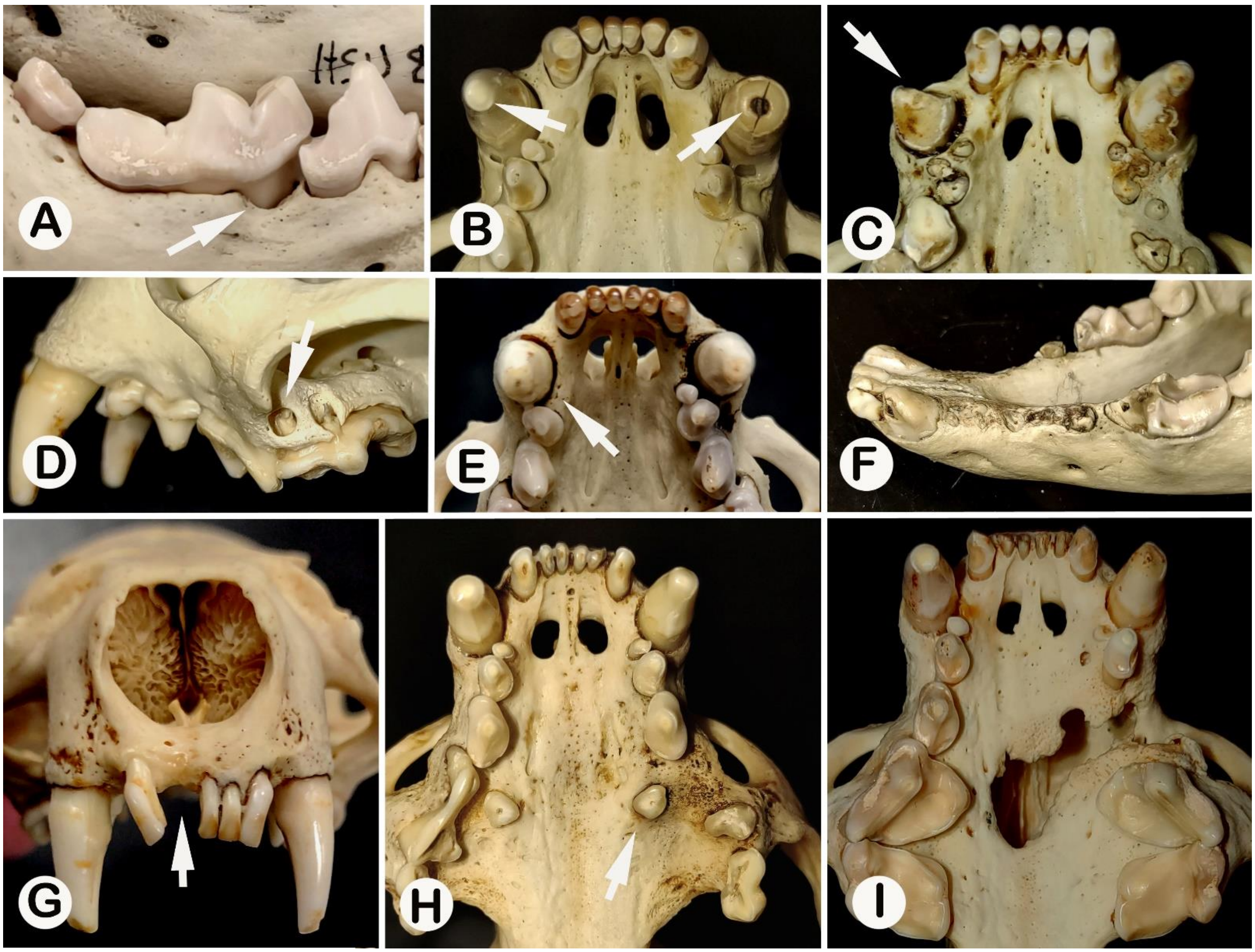

Figure 2. Dental pathologies observed in river otters from Arkansas. A: attrition represented by alveolar thinning (arrow); B: attrition on canine (left arrow) and abrasion leading to exposure of the pulp cavity (right arrow); C: tooth fracture (arrow) and premolar teeth broken at the root; D: alveolar thinning of molar (arrow); E: missing tooth (possibly congenital); F: severe tooth wear through abrasion, exposed canine pulp cavity, and loss by breaking; G: missing incisors with healed bone; H: broken teeth (note only root remaining at arrow), with all teeth smoothed by attrition – note also bone infection causing porous appearance; I: missing teeth due to gunshot trauma (bullet recovered from sinuses) with healing of bone.