A pathological condition in elephant dentition

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Abstract

Growth of molars in the African elephant (*Loxodonta africana*) is redescribed as background for a pathological dental condition reported from four elephants in Kenya, one in Zimbabwe (where other cases have been seen) and 84 in Uganda. Apparently chronic in two Uganda populations, it was found in both sexes of all ages. Speculatively attributed to the malnutrition described by Laws, in the individual the condition seems temporary with evidence of recovery. While of veterinary interest, at a population level the condition may warn of nutritional deficiency with management implication.

Additional Key words: jaw abscesses and molar cavities

Résumé

La croissance des molaires de l'éléphant d'Afrique (*Loxodonta africana*) est passée en revue pour comprendre une condition pathologique de la dentition signalée chez quatre éléphants au Kenya, un au Zimbabwe (où l'on en a vu d'autres) et 84 en Ouganda. Cette condition était apparemment chronique chez deux populations ougandaises et se trouvaient dans les deux sexes de tous âges. Spécialement attribuée à la malnutrition décrite par Laws, elle semble temporaire dans l'individu et pourrait être renversée. D'intérêt vétérinaire, au niveau de la population, la condition peut signaler une déficience nutritionnelle et avoir des conséquences de gestion.

Mots clés supplémentaires: abcès de la mâchoire et cavités molaires.

Introduction

The subject of this paper was first reported by Laws R. M. (1966) in his paper on aging elephant (*Loxodonta africana* Blumenbach) from their lower jaw dentition in the following extract:

An interesting feature of the Murchison Falls Park collection was the number of jaws with bony growths or alveolar abscesses. Some ten per cent showed this feature on one or both sides, often with a conspicuous drainage channel having developed through the bone of the mandible. Often the related tooth had worn excessively so that the pulp cavity was exposed.

He was referring to a collection of elephant jaws from natural mortality made at his request in the Murchison Falls National Park (MFNP) and the Queen Elizabeth National Park by the Uganda National Parks staff. No differentiation was made between MFNP's two populations that were separated by the Nile; that to the north identified in this paper as MFPN, that to the south as MFPS. Subsequently 2000 elephant were culled in that park (Laws et al., 1975) from which the incidence of Laws' pulp exposures, bony growths and alveolar abscesses (hereafter–'the condition') in two separate populations was established. The conclusion that they are aspects of the same pathology is the subject of this paper.

A brief recapitulation of the manner of elephant mandibular molar development from Sykes (1966) and Laws (1966) helps interpret this evidence (the progression of maxillary molars is assumed to be similar, but this has not been confirmed). In an elephant's life six molars (the two premolars being counted as molars) follow one another in succession, each larger than its predecessor. No more than one or a part of its successor is in use at any one time, and at the peak of its functional life each tooth effectively fills the short jaw (the molar bed).

Molar formation starts high in the angle of the jaw, from a pulp bed on the ventral floor of the alveolus. Out of this a series of laterally compressed cones grow upward into the alveolar space (Figure 1; see colour plates: page iii). Growth commences anteriorly, the pulp sending up in succession a set of parallel cones. The first and last are usually the smallest; the largest being those in the second third of the array. Reaching full size, each pulp cone starts regressing, replacing itself, first with a coat of enamel of ca. 2–4 mm thick, and then a deposition of dentine producing a series of parallel, laterally compressed enamel coated dentine lamellae. In due course their bases fuse (Figures 2a, 2b; see colour plates: page iii).

The final step in the tooth's formation is when the emerging now fused lamellae are embedded in a block of cementum. As the tooth moves forward and out into the posterior half of the molar bed, enamel deposition ceases with the fusion of the cones' bases, but fused dentine coated with cementum grows on downward into the mandible as massive roots.

However, as the tooth progresses into the anterior half of the molar bed, this process is reversed. Above the gingiva the tooth is worn down by mastication, exposing first the lamellae tips and then with further wear, lamellae cross-sections as dentine-filled enamel lozenges (Figure 3; see colour plates: page iii). Being softer, the cementum outside and dentine inside the enamel lozenges wears faster than the enamel, which then stands out as sheering edges that shred vegetation on which elephants feed. As the tooth reaches the anterior edge of the molar bed almost all enamel has worn away. Within the jaw the fused cementum and dentine roots are progressively resorbed and replaced by bone. At the front edge of the alveolus little of the tooth remains within the jaw so that wear of the molar crown more or less matches resorption of its content within the jaw until what little is left breaks off and is lost. Various stages in the process are illustrated in Figure 4; see colour plates: page iii.

Methods

Elephant culling and data collecting are described by Laws et al. (1975) at a time when elephant overabundance was a major conservation problem in Murchison Falls National Park (Uganda). Each specimen was allocated a serial number. A panel of skin and underlying tissue was removed from all elephant jaws and the specimen's serial number stamped into the bone with hammer and punch dies before the jaw was detached from the carcass. Thereafter jaws were immersed underwater until all soft tissues had decomposed and been removed by fish and other aquatic life, before being dried and stored for aging using Law's dentition key.

Jaws from a sample of 700 elephant culled north of the Nile (MFPN GMU 700–1,400), and 600 taken south of that river (MFPS GMU 1401–2000) were examined by eye for the condition reported by Laws and its presence recorded in three categories: (i) a cavity or cavities but without obvious jaw deformation, discharge fistulae or obvious abscessing in the bone, (ii) cavities accompanied by such evidence in the bone and (iii) a swollen jaw bone without associated cavities or abscessing, and with or without whorls or indication in the bone grain of previous but now healed trauma. This latter category was classified as 'healing'. Subsequently the right mandible from a 25 year-old elephant MFPS 1995 was bisected longitudinally and photographed to illustrate the condition within the mandible (Figure 5; see colour plates: page iv), and a typical dorsal view of swollen jaw was also photographed (Figure 6; see colour plates: page iv). Where appropriate, Chi^2 tests of association (with Yates' correction) were carried out. Calculations were done in Microsoft Excel.

Results

Tables 1 and 2 document cases of the condition seen in respectively MFPN 700 (41=5.9%) and MFPS 600 (43=7.2%) lower jaws examined, together with the elephants' serial numbers, sexes and ages. The tables show that the condition occurs across the range of ages from 1 to 59 y. There is no significant difference of the condition's presence between the two populations (Chi^2=0.712795, $p < 0.3985$). Its distribution between the sexes was males MFPN 322=46%, MFPS 348=54% and females MFPN 378=58%, MFPS 252=42%. Summed, in the two populations the condition occurred in 670 males and 630 females and incidence between the sexes was not statistically different (Chi^2=0.190476, $p < 0.6625$). Similarly the distribution of the condition between left and right ramii was also not statistically different (Chi^2=0.01449, $p < 0.9042$).

However, cases of the condition occurring simultaneously in both left and right rami–MFPS 13 and MFPN 2 was significantly different (Chi^2=4.064392, p <0.0438*). These cases where the condition occurred in both rami in the same individual were significantly greater than expected from the frequency of single cases (Chi^2=91.26361, p <1.26E-21***). There were 12 healed or healing cases in MFPN and only two in MFPS and the incidence of healing was significantly different between the two populations (Chi^2=7.470902, p <0.00627**).

All cases were contained within the forward part of the molar bed, and only in the area where resorption of tooth roots within the alveolus takes place. No cavity, abscess or extraneous matter was observed in or beneath incoming molars in the posterior section of the molar bed. Small abscesses at the anterior end of the molar bed appeared to discharge forwards under the remains of the departing molar. However, bigger abscesses that developed further back in the mandible (but still in the anterior half of the molar bed) discharge was through a fistula of up to ca. 2 cm diameter down through the jaw, exiting through the skin on its underside. There were two cases where the bony rim of the alveolus was so eroded that some discharge must have occurred into the mouth (GMU 1233 & GMU 1552).

The cavities through a molar's working surface reported by Laws were only seen through the dentine within the enamel lozenge of a lamella (as termed by Laws (1966)). All were fenestrations through into the alveolus below. Yet there was no evidence of any developmental stages as dark spots, small pits or depressions in the tooth's dorsal surface as occur, for example, with caries in human teeth. Without evidence of formative stages on the tooth's working surface, ergo, they had developed from below in the alveolus.

Evolution of the condition can be followed in Figure 5. The molar in use is an M4, which might reasonably have originally had nine lamellae (Laws, 1966). On this assumption the first four have gone or left vestigial bits on top of an abscessed area filled with black matter. With L5–L6 the crowns are worn down, cavities in both are clearly channelling black, compacted vegetable matter into the alveolus—now an abscess chamber. With L7, 8 & 9 in decreasing order, the process advancing upwards from below is apparent in the dark matter, forced under pressure up into the space that had earlier been filled with dentine–as obvious in the lamellae of the incoming M5. It illustrates the process whereby erosion of the dentine from within the alveolus would reach a point where it was so thin that it collapsed under mastication pressures from above, forming a new channel into the alveolus.

In Figure 5 the abscess mass was nearly the width of the molar and bone surrounding it was white, somewhat spongy, and mandible strength had been severely compromised. Not apparent from the photograph is that on either side of this weakened area, the ramus was swollen with hard dense bone to double its normal width, acting as reinforcement around the weakened abscessing area. Figure 6 shows such typical swelling in a case from Zimbabwe in which M4 is the affected outgoing tooth with M5 the incoming replacement.

As Laws (1966) noted, with few exceptions, molar progression is synchronous between left and right mandibles. Somewhat surprisingly, this synchrony persisted despite the presence of the condition in one mandible, with little evidence that it made an elephant favour chewing on the healthy side opposite, or disrupt the synchrony of molar progression. (Figure 6; see colour plates: page iv). Seemingly, the condition did not cause much discomfort.

No cavities were observed in an emerging molar in the posterior half of the molar bed, i.e. while the lamellae were still developing, were still dentine filled and developing as roots displacing bone. Maxillary molars were not examined and whether the condition exists in them is not known.

Discussion

The condition has been described from three Uganda populations, Queen Elizabeth National Park, MFPN and MFPS. In Kenya it was seen in the left ramus of a female elephant WLS 115 culled in Tsavo, and two cases in Laikipia, one in a three-year-old elephant on Suyian Ranch in 2010, another on Ol Jogi ranch in a mid-life male elephant (veterinarian Veejay Varma, pers comm.), and a fourth in a captive three year old elephant in Langata (originally from Laikipia), Kenya, 2010 (veterinarian Sanjay Gautama, pers. comm.). Colin Craig (pers. comm.) has seen examples of the condition in Zimbabwe, and confirmed by Fiona Stansfield who provided Figure 6. However, only in the two Uganda populations of MFPN and MFPS was it a chronic 'population' condition. Elsewhere it seems to have been occasional.

It may be more widespread than these records imply. Diagnosis is difficult in the living animal without close inspection or unless an abscess is actively discharging under the jaw. Its incidence only became clear where collections of lower jaws, free of soft tissue, were available either collected from natural or other mortality in the field or, as in this case, where a reduction programme presented sufficient material to analyse it at a population level.

Laws (pers. comm.) initially opined that the swollen mandibles reminded him of Paget's osteomyelitis. However, evidence that the swelling regresses and is transient, and that the condition only occurs in the anterior half of the molar bed makes Paget's osteomyelitis unlikely.

Possibly the condition involves a form of Actinomycosis which, in cattle and other herbivores usually arises when foreign matter penetrates down into the alveolus beside or between molars (D Röttcher, pers. comm.). No such case was observed with elephants. Such accidental events would, in any case, have involved incoming molars in the posterior molar bed as well as those outgoing in the anterior aspect, arguing against classical Actinomycosis. Notwithstanding this, the manner in which the remnants of a departing molar breaks off exposing temporary trauma in the gingiva would be obvious sites for bacterial infection through which, among others, *Actinomyces* could enter the anaerobic alveolar environment. It is also conceivable that such primary infection might be the accelerant of premature dentine resorption allowing channels to open up to the tooth's working surface as observed. Yet while bacterial origins cannot be ruled out, the possibility is at odds with the condition occurring only where molar resorption takes place and not infecting a wider area.

The condition's chronic appearance in MFPN and MFPS suggests an alternative interpretation of its genesis. Laws (1968, 1969), Laws et al (1975) and McCullagh (1969a, b) reported both MFPN and MFPS populations were nutritionally deficient. Compared to populations in Kenya and Tanzania (Mkomasi), both MFPN and MFPS elephants grew slower, were lighter at age, the onset puberty was delayed and their calving intervals were longer–all attributed to nutritional stress. It was most severe in MFPS where natural mortality had exceeded natality substantially for two decades without human predation. That there were more cases of recovery in MFPN and the greater incidence of simultaneous abscesses in both rami in MFPS, are both in keeping with their respective nutritional conditions.

With some caution, given the limited clinical data available, it is logical to posit a connection between nutrition and the scale of the condition in MFPN and MFPS. Either the quality of dentine was defective (not supported by subjective judgement of quality in the animals' tusks) or a deficiency had upset the process of molar resorption in the anterior aspect of the mandible, causing dentine to be removed faster than normal, leading to the cavities and abscessing. If the condition was caused by an infectious organism its presence in only the anterior part of the ramus, even when both ramii are affected, is difficult to account for. Tentatively, therefore, it is attributed to a direct nutritional rather than infectious cause.

From a veterinary view point, the massive jaw swelling and discharge from under the jaw may look formidable, but they appear subordinate to and do not disrupt the inexorable processes of molar progression in which the defective tooth and the condition is replaced by a healthy larger, new molar. With the cause of abscessing gone the jaw reverts to its original shape. Incomplete as the evidence may be, it seems that the condition is local, temporary and can heal without

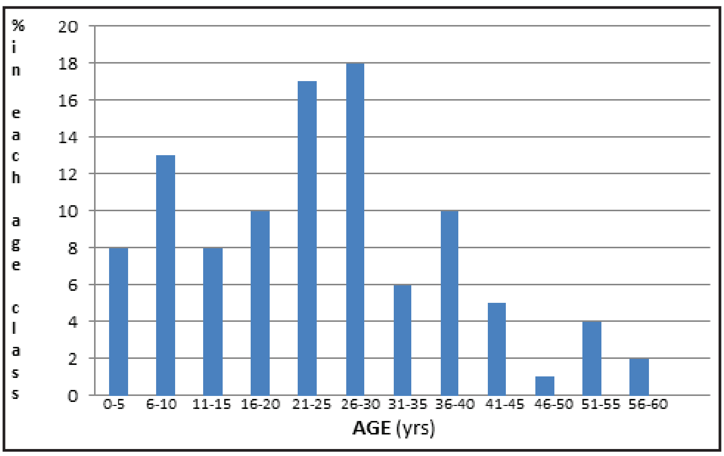

Figure 7. A histogram presenting cases of the condition in 5-year age classes.

Table 1. Forty one cases of the condition from a sample 700 MFPN elephants arranged in an ascending age order (aged according to Laws, 1966) M=Male, F=Female, Active right, left or both=the condition present in the designated mandible. Healed right or left=no cavity or abscess present, but scar on the underside of the mandible or a regressing swelling evidence that the condition had previously been present.

		MFPN		n=700		41 cases of the condition = 5.9% of sample		
M	**F**	**Age/years**	**Active right**	**Active left**	**Active both**	**Healed right**	**Healed left**	**Field notes**
1		4		1				
	1	5		1				
	1	5		1				
1		5		1				Cavity to pulp M3
1		6		1				
	1	7		1				Swelling very large
1		8	1					
1		8	1					
1		10		1				
1		14					1	
1		15		1				
	1	15	1					
1		15				1		
1		15	1					
1		15					1	
	1	16				1		
	1	20		1				
	1	22	1					
1		22		1				
	1	22					1	
	1	22				1		
1		23	1					
	1	23					1	Large - no cavity to pulp
1		24	1					
1		25		1				
1		26		1				
	1	26			1			Massive caries
1		26					1	Healed
1		26				1		
	1	27		1				No drainage but swollen
1		27	1					
	1	29	1					
	1	30	1					
	1	30					1	Swelling regressing
	1	35	1					
	1	36	1					
	1	40					1	Indication of previous abscess
	1	40	1					Large cavity in outgoing M5
	1	48		1				M5 many cavs; abscess discharging into mouth
	1	58				1		
	1	59			1			
19	22		13	14	2	5	7	**Total 41 cases of the condition**

Table 2. Forty-three cases of the condition from a sample 600 MFPS elephants arranged in an ascending age order (aged according to Laws 1966). M=Male, F=Female, Active right, left or both=the condition present in the designated mandible. Healed right or left=no cavity or abscess present, but scar on the underside of the mandible or a regressing swelling evidence that the condition had previously been present.

		MFPS		n=600		43 cases of the condition = 7.2% of sample		
M	**F**	**Age/years**	**Active right**	**Active left**	**Active both**	**Healed right**	**Healed left**	**Field notes**
1		1	1					forward of m2
1		2.5	1					cav in m2
1		3	1					both m3s caries
	1	6			1			cavs in m3
1		8			1			every lamella in m3 with cavs
1		8		1				cavs in both m3s
1		9			1			both jaws swollen
1		10	1					both m3s caries, large hollows underneath
1		11			1			
1		16		1				very swollen
1		16	1					
1		16		1				cavs in m4 abscess retarded in m5
1		17		1				cavs in m4s
1		17			1			m4 largely destroyed by abscess
1		18		1				
	1	22	1					abscess m4 little cementum between it & m5
1		23	1					m4 rotted away almost entirely
	1	24			1			duct not yet opened from abscess
	1	25	1					
1		25		1				ramus collected
1		26		1				in m4s very large
1		26			1			cavs in m4 but no visible abscess
	1	25		1				slight swelling
1		28	1					many cavs in m5s
1		28			1			cavity in m5
	1	30	1					
	1	30		1				cav in m5
	1	31		1				m5 4 cavs v. low crown
	1	32	1					intense resorption in m5 before time
	1	32			1			apparently healed
	1	34	1					CAVS m5
1		36	1					remains of m5 abnormally worn down
	1	37			1			unopened
	1	39		1				
	1	39				1		cavity in m5
1		40		1				duct open left not yet right
	1	41			1			cavs in m6s
1		44			1			4 caries and grossly abscessed
1		45		1				cavs in m6
	1	45		1				
1		52				1		rims of alveoli eroded very large swellings
	1	53			1			M6 with 4 cavs and large hollow under tooth
	1	55	1					
25	18		14	14	13	2	0	**Total 43 cases of the condition**

surgical or other intervention.

The data on chronic molar abscessing within two elephant populations that were subsequently all but wiped out during political upheavals of Uganda's Obote-Amin era may today seem of only historical and somewhat arcane interest. Yet if the condition was caused by nutritional deficiency accelerating premature resorption of outgoing molars, its appearance in extant populations might be advance warning of developing nutritional problems, and have value in elephant management. As reported, the condition first came to notice by collecting jaws from natural mortality. Before that its presence may have been seen previously as an oddity not worth documenting, and only assumed a broader interest once perceived as a population phenomenon. Collecting and storing jaws as routine practice from, not only elephants, but all mammals in conservation areas, will not only produce durable evidence of age, size, sex and bone quality that can be repeatedly consulted, but give insight into local population biologies and should be encouraged.

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All data and photos (where not acknowledged) have not been previously published.

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