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DENTAL MACROWEAR IN CATARRHINE PRIMATES: VARIABILITY ACROSS SPECIES

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INTRODUCTION & OBJECTIVES

Dental macrowear is caused by a cumulative loss of enamel and dentine, principally due to attrition and abrasion, reflecting the interaction between feeding behavior and a species' environment [1,2]. Previous studies have quantified dental macrowear in relation to absolute time (age) in individually known primates, or relative tooth wear rates between molars, and these have demonstrated variability in dental macrowear rates among species [3-7]. Also, increased consumption of gritty foods, dust or soil consumption, and seasonal droughts have been related to higher tooth wear rates in some species; dental wear may also be related to fitness components [5,6, 8-11]. However, within primates, comparative data that would allow delineating the contribution of these factors are lacking.

In the present study, we analyze variability in dental macrowear in twenty living catarrhine species (Table 1), using **Percent of Dentine Exposure (PDE)** as a proxy of dental macrowear. Our specific aims are to:

-Analyze the dental macrowear rate between M1 and M3, following a standard approach [3,7] to detect **variability across species**.

- Test possible **sources of variation** in dental macrowear in catarrhines, including: Superfamily (Cercopithecoidea or Hominoidea), general diet and enamel thickness (in mm).

MATERIAL & METHODS

Table 1. Analyzed sample. Diet categories: D (durophagous), Fr (frugivore) and Fo (folivore). Enamel thickness measured in mm, following Kay (1981) [12]. Osteological collections and primatological sites: Powell-Cotton Museum, Kent (PCM) , Royal Museum for Central Africa, Tervuren (RMCA), American Museum of Natural History, New York (AMNH), National Museum of Natural History, Washington DC (NMNH), Staatssammlung fuer Anthropologie und Palaeoanatomie, München (SAPM), Centre de Recherches en Sciences Naturelles, Lwiro (CRSN), Mountain Gorilla Skeletal Project (MGSP), Bwindi Skeletal Project (BSP), Mandrillus Project (MP), Amboseli Baboon Research Project (ABRP), Taï National Park (TNP). *Cercopithecus sp.* includes *C. diana* and *C. campbelli*.

Species and/or population	#M1	#M3	Enamel thickness (mm)	Diet	Collections/Sites
Cercopithecoidea					
Cercocebus agilis	8	7	0.83	D	PCM, RMCA
Cercocebus torquatus	11	11	0.93	D	PCM
Cercopithecus ascanius	13	10	0.49	Fr	RMCA
Cercopithecus cephus	26	26	0.52	Fr	PCM
Cercopithecus kandti – Virunga	24	24	0.56	Fo	MGSP
Cercopithecus sp. – Taï	42	42	0.50	Fr	TNP
Colobus angolensis	10	10	0.50	Fo	CRSN
Lophocebus albigena	39	37	0.81	D	PCM, RMCA, CRSN
Mandrillus sphinx – Lékédi Park	37	12	1.13	D	MP
Papio cynocephalus - Amboseli	97	78	0.92	D	ABRP
Piliocolobus badius	25	25	0.54	Fo	PCM
Hominoidea					
Gorilla b. beringei – Bwindi	10	9	0.93	Fr	BSP
Gorilla b.beringei – Virunga	86	59	0.95	Fo	MGSP, RMCA, NMNH, AMNH
Gorilla b.graueri	48	37	0.91	Fr	RMCA
Gorilla g. gorilla	35	35	0.95	Fr	PCM, AMNH
Hylobayes moloch	30	22	0.34	Fr	SAPM
Pan paniscus	57	39	0.72	Fr	RMCA
Pan t. schweinfurthii	58	47	0.75	Fr	RMCA
Pan t. troglodytes	11	11	0.75	Fr	PCM, RMCA
Pongo p. pygmaeus	33	23	1.05	D	SAPM
TOTAL	**700**	**564**			

•Photos of the occlusal surfaces of teeth were obtained from catarrhine primates curated in several osteologic collections, from naturally-accumulated collections, and from tooth replicas obtained in wild populations (Table 1).

•PDE was calculated for the first (M1) and third (M3) permanent molar, as a quantitative indicator of tooth wear (Figure 1). In those individuals where mandible and maxilla were available, we used an average of both.

• We performed linear regressions to determine the relationship between PDEM3 changes in relation to PDEM1 for each species (Figure 2).

• We used analyses of variance (ANCOVA) and linear models to determine relationships between PDEM3 and several factors: PDEM1, Superfamily, general diet and average enamel thickness, measured following Kay (1981) [12].

• All analyses were performed with R version 3.3.1 [13].

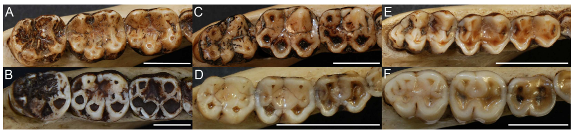

Figure 1. Mandibular molar occlusal images (M3, M2, M1) showing tooth crowns with different percent of dentine exposure (PDE) in different species. *Pan t. troglodytes* PCM-M77 (A), *Gorilla b. beringei* Bwindi BW09 (B), *Gorilla g. gorilla* PCM-M58 (C), *Cercopithecus cephus* PCM-M94 (D), *Piliocolobus badius* PCM-M230 (E) and *Cercocebus torquatus* PCM-M77 (F). Scale bar = 1 Cm. Photos by LB-S and JG.

RESULTS

•Linear regressions between PDEM1 and PDEM3 demonstrate great variability across species (Figure 2).

• Cercopithecoidea show higher tooth wear rates and greater variability than Hominoidea (Figure 3).

• Many folivore and durophagous primates show higher tooth wear rates than frugivore species (Figure 4).

• The analysis of covariance model shows that Superfamily, general diet and enamel thickness explain tooth wear rates (Figure 4, Table 2).

• The linear model shows similar results, and determines that the frugivore species present significantly lower tooth wear rates than folivores and durophagous species (Table 3).

Figure 2. Linear regressions for predicting PDEM3 from PDEM1 for each species.

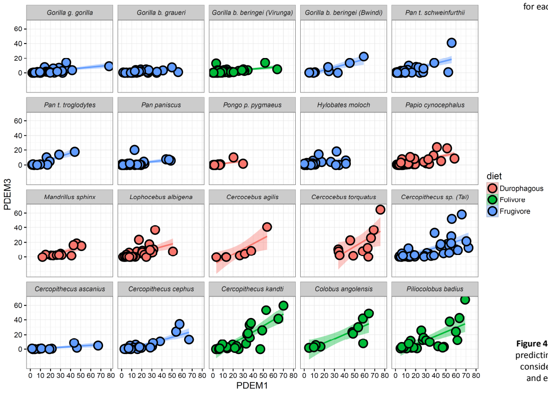

Figure 3. Linear regressions for predicting PDEM3 with PDEM1 for each species, considering Superfamily groups (Cercopithecoidea and Hominoidea).

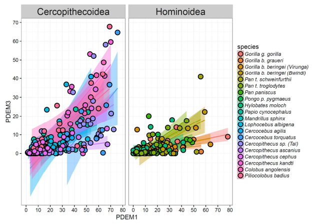

Table 2. Analyses of variance model to explain PDEM3 from PDEM1, Superfamily (Cercopithecoidea or Hominoidea), general diet (durophagous, frugivore or folivore), and enamel thickness (in mm). All explanatory variables are significant (P<0.05).

Factor	Df	Sum sq.	F-value	P-value
PDEM1	1	23,774.3	611.01	**<0.001**
Superfamily	1	370.0	9.51	**0.002**
Diet	2	779.6	10.02	**<0.001**
Enamel	1	478.5	12.30	**<0.001**
PDEM1*Diet	2	795.0	20.43	**<0.001**
PDEM1*Enamel	1	1277.4	32.83	**<0.001**
PDEM1*SuperFam	1	384.1	9.87	**0.002**
Residuals	553	21,517.2		

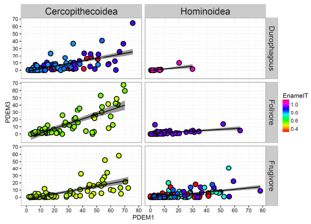

Figure 4. Linear regressions for predicting PDEM3 with PDEM1 considering Superfamily ,diet, and enamel thickness (color gradient in mm).

Table 3. Linear model to explain PDEM3 from PDEM1, Superfamily (Cercopithecoidea or Hominoidea), general diet (durophagous, frugivore or folivore), and enamel thickness (in mm). Significant explanatory variables in bold (P<0.05).

Factor	Estimate	Df	F-value	P-value
Intercept	5.606			**0.009**
PDEM1	0.357	1	534.64	**<0.001**
Superfamily		1	8.32	**0.004**
Hominoidea	0.609			0.532
Diet		2	8.77	**<0.001**
Folivore	0.528			0.627
Frugivore	-3.280			**0.007**
Enamel	-7.650	1	10.76	**0.001**

DISCUSSION & CONCLUSIONS

• Though most primate specimens housed in osteological collections are of unknown age, the relationship between PDEM1 and PDEM3 reveals significant variation in dental macrowear rate (Figure 2).

• Tooth wear rate variability can be explained by several factors. Higher tooth wear rates are found in Cercopithecoidea, folivore and durophagous, and thin-enameled species.

• Differences between Cercopithecoidea and Hominoidea may be caused by differences in dental morphology, or even differences in tooth eruption patterns.

• Higher tooth wear rates in folivore and durophagous primates, especially colobines, may be related to the higher chewing rates to process tough foods [14].

• Enamel thickness has to be considered when studying tooth wear in primates, as it explains part of the variability observed in PDE examined here as a proxy for dental macrowear.

• Further studies are needed to better understand dental macrowear variability in primates, including additional research incorporating individually known primates with established chronological age, and associated data on dietary composition, dental emergence, enamel thickness and other properties (e.g., hardness), and occlusal topography [11].

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REFERENCES

[1] Phillips-Conroy JE et al. 2000. Quantitative assessment of occlusal wear and age estimation in Ethiopian and Tanzanian baboons. In: Whitehead PF, Jolly CJ, editors. Old world monkeys. Cambridge: Cambridge University Press. p 321–340. **[2]** Cuozzo FP & Sauther ML. 2012. What is Dental Ecology?. Am J Phys Anthropol 148:163–170. **[3]** Elgart AA. 2010. Dental wear, wear rate, and dental disease in the African apes. Am J Primatol 72:481–491. **[4]** Galbany J et al. 2011. Age and individual foraging behavior predict tooth wear in Amboseli baboons. Am J Phys Anthropol 144:51–59. **[5]** Galbany J et al. 2014. Age-related tooth wear differs between forest and savanna primates. PLoS One 9:e94938. **[6]** Galbany J et al. 2016. Tooth wear and feeding ecology in mountain gorillas from Volcanoes National Park, Rwanda. Am J Phys Anthropol 159: 457-465. **[7]** Morse PE et al. 2013. Dental wear among Cercopithecid monkeys of the Taï Forest, Côte d'Ivoire. Am J Phys Anthropol 150:655–665. **[8]** Kojola I et al. 1998. Foraging conditions, tooth wear and herbivore body reserves: a study of female reindeer. Oecologia 117:26–30. **[9]** Logan M & Sanson GD. 2002. The effect of tooth wear on the feeding behaviour of free-ranging koalas (*Phascolarctos cinereus*. Goldfuss). J Zool Lon 256:63–69. **[10]** King SJ et al. 2005. Dental senescence in a long-lived primate links infant survival to rainfall. Proc Nat Acad Sci USA 102:16579–16583. **[11]** Glowacka H et al. 2016. Age-related changes in molar topography and shearing crest length in a wild population of mountain gorillas from Volcanoes National Park, Rwanda. Am J Phys Anthropol 160: 3–15. **[12]** Kay R. 1981. The nut-crackers - A new theory of the adaptations of the ramapithecinae. Am J Phys Anthropol 55:141–151. **[13]** R Core Team. 2016. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/. **[14]** Dunham NT & Lambert AL. 2016. The role of leaf toughness on foraging efficiency in Angola black and white colobus monkeys (*Colobus angolensis palliatus*). Am J Phys Anthropol 161:343–354.