zoosystema

2026 • 48 • 19

Craniodental pathologies and irregularities in the giraffe (*Giraffa* spp.)

Nikolaos KARGOPOULOS, Julian FENNESSY, Jesús MARUGÁN-LOBÓN, Anusuya CHINSAMY, Michael BROWN, Stephanie FENNESSY, Arthur MUNEZA, Bernard R. AGWANDA, Ogeto MWEBI, Moses OTIENDE, Frederick LALA, Alice PETZOLD, Sven WINTER, Abdoul Razack Moussa ZABEIROU & Sara FERGUSON

art. 48 (19) — Published on 25 August 2026
www.zoosystema.com

PUBLICATIONS SCIENTIFIQUES
MUSÉUM NAL HIST NATURELLE

Couverture / *Cover*:
Examples of craniodental pathologies and irregularities in giraffe, including neoplasia, cleft palate, trauma, unusual dental morphology, and periodontitis.

Zoosystema est indexé dans / Zoosystema *is indexed in:*
- Science Citation Index Expanded (SciSearch®)
- ISI Alerting Services®
- Current Contents® / Agriculture, Biology, and Environmental Sciences®
- Scopus®

Zoosystema est distribué en version électronique par / Zoosystema *is distributed electronically by:*
- BioOne® (http://www.bioone.org)

Les articles ainsi que les nouveautés nomenclaturales publiés dans *Zoosystema* sont référencés par / *Articles and nomenclatural novelties published in* Zoosystema *are referenced by:*
- ZooBank® (http://zoobank.org)

Zoosystema est une revue en flux continu publiée par les Publications scientifiques du Muséum, Paris / **Zoosystema** *is a fast track journal published by the Museum Science Press, Paris*

Les Publications scientifiques du Muséum publient aussi / *The Museum Science Press also publish:*
Adansonia, ***Geodiversitas***, ***Anthropozoologica***, ***European Journal of Taxonomy***, ***Naturae***, ***Cryptogamie*** **sous-sections** ***Algologie***, ***Bryologie***, ***Mycologie***, ***Comptes Rendus Palevol***.

Diffusion – Publications scientifiques Muséum national d'Histoire naturelle
CP 41 – 57 rue Cuvier F-75231 Paris cedex 05 (France)
Tél.: 33 (0)1 40 79 48 05 / Fax: 33 (0)1 40 79 38 40
diff.pub@mnhn.fr / https://sciencepress.mnhn.fr

ISSN (imprimé / *print*): 1280-9551/ ISSN (électronique / *electronic*): 1638-9387

Craniodental pathologies and irregularities in the giraffe (*Giraffa* spp.)

Nikolaos KARGOPOULOS
Department of Biological Science, University of Cape Town, Rondebosch, Cape Town (South Africa),
and Giraffe Conservation Foundation, PO Box 86099, Windhoek (Namibia)
nikoskargopoulos@gmail.com (corresponding author)

Julian FENNESSY
Giraffe Conservation Foundation, PO Box 86099, Windhoek (Namibia),
and School of Biology and Environmental Science, University College Dublin, Dublin (Ireland)

Jesús MARUGÁN-LOBÓN
Department of Biological Science, University of Cape Town, Rondebosch, Cape Town (South Africa),
and Unidad de Paleontología, Department of Biology,
Universidad Autónoma de Madrid, 28049, Cantoblanco, Madrid (Spain),
and CIPb-UAM, Center for the Integration in Paleobiology,
Universidad Autónoma de Madrid, 28049, Cantoblanco, Madrid (Spain)

Anusuya CHINSAMY
Department of Biological Science, University of Cape Town, Rondebosch, Cape Town (South Africa)

Michael BROWN
Stephanie FENNESSY
Arthur MUNEZA
Giraffe Conservation Foundation, PO Box 86099, Windhoek (Namibia)

Bernard R. AGWANDA
Ogeto MWEBI
National Museums of Kenya, PO Box 40658-00100 Nairobi (Kenya)

Moses OTIENDE
Frederick LALA
Wildlife Research and Training Institute, PO Box 842 20117-00100 Naivasha (Kenya)

Alice PETZOLD
Institute of Biochemistry and Biology, University of Potsdam,
Karl-Liebknecht Str.24-25, 14476, Potsdam (Germany)
and Museum für Naturkunde – Leibnitz Institute for Evolution and Biodiversity Science,
Invaliden str. 43, 10115, Berlin (Germany)

Sven WINTER
Senckenberg Biodiversity and Climate Research Centre,
Senckenberganlage 25, 60325 Frankfurt am Main (Germany),
and Research Institute of Wildlife Ecology, University of Veterinary Medicine, Vienna,
Savoyenstr. 1, 1160 Vienna (Austria)

Abdoul Razack Moussa ZABEIROU
Giraffe Conservation Foundation, PO Box 86099, Windhoek (Namibia),
and Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague,
Kamýcká 129, 165 00, Prague (Czech Republic)

Sara FERGUSON
Giraffe Conservation Foundation, PO Box 86099, Windhoek (Namibia)

Submitted on 27 August 2025 | Accepted on 27 January 2026 | Published on 25 August 2026 urn:lsid:zoobank.org:pub:C8A3FC54-671D-40CD-8183-D33332733AF9

Kargopoulos N., Fennessy J., Marugán-Lobón J., Chinsamy A., Brown M., Fennessy S., Muneza A., Agwanda B. R., Mwebi O., Otiende M., Lala F., Petzold A., Winter S., Zabeirou A. R. M. & Ferguson S. 2026. — Craniodental pathologies and irregularities in the giraffe (*Giraffa* spp.). *Zoosystema* 48 (19): 590-621. https://doi.org/10.5252/zoosystema2026v48a19. http://zoosystema.com/48/19

ABSTRACT

Giraffe (*Giraffa* spp.) are some of the most iconic representatives of African megafauna; yet, published data on their pathologies in general remain scarce. Our study reported multiple cases of craniodental pathologies and irregularities in all four species of giraffe based on a large dataset comprising 516 skulls. Dental irregularities included abnormal morphologies, misaligned or absent teeth, irregular dental wear, and dental fractures. Cranial cases include periodontitis (observed in a considerable proportion of the dataset; n=206, 39.9%), ossicone asymmetry in size and orientation (due to developmental variations or trauma), trauma possibly caused by intraspecific aggression, neoplasia, wry nose, and cleft palate. The causes of these pathologies appear to be either congenital (e.g., wry nose), behavioural (e.g., fighting injuries), or environmental (e.g., diet-related periodontitis). This preliminary report of giraffe cranial pathologies/irregularities serves as a foundational dataset to enable the detection of similar deformities in different giraffe species, and perhaps in other species as well.

KEY WORDS
Artiodactyla,
cleft palate,
Giraffidae,
neoplasia,
periodontitis,
trauma.

RÉSUMÉ

*Pathologies et irrégularités crânio-dentaires chez la girafe (*Giraffa *spp.).*

Les girafes (*Giraffa* spp.) comptent parmi les représentants les plus emblématiques de la mégafaune africaine. Pourtant, les données publiées sur leurs pathologies en général restent rares. Notre étude a rapporté de multiples cas de pathologies et d'irrégularités crânio-dentaires chez les quatre espèces de girafes, sur la base d'un vaste ensemble de données comprenant 516 crânes. Les irrégularités dentaires comprenaient des morphologies anormales, des dents mal alignées ou absentes, une usure dentaire irrégulière et des fractures dentaires. Les cas crâniens comprenaient la parodontite (observée dans une proportion considérable de l'ensemble de données ; n = 206, 39,9 %), une asymétrie de taille et d'orientation des ossicones (due à des variations développementales ou à un traumatisme), un traumatisme possiblement causé par une agression intraspécifique, une néoplasie, un nez tordu et une fente nasale. Les causes de ces pathologies semblent être congénitales (par exemple, un nez tordu), comportementales (par exemple, des blessures lors de combats) ou environnementales (par exemple, une parodontite liée à l'alimentation). Ce rapport préliminaire sur les pathologies/irrégularités crâniennes des girafes sert de base de données de référence pour permettre la détection de déformations similaires chez différentes espèces de girafes, et peut-être chez d'autres espèces également.

MOTS CLÉS
Artiodactyla,
fente palatine,
Giraffidae,
néoplasie,
parodontite,
traumatisme.

INTRODUCTION

Giraffe (genus *Giraffa* Brünnich, 1772) are among the most iconic and sentinel animals of African megafauna, currently found across sub-Saharan Africa from Niger to South Africa (O'Connor *et al.* 2019; Brown *et al.* 2021). Despite their spectacular physical adaptations, many species and subspecies of giraffe face the threat of extinction due to anthropogenic impacts such as habitat loss and fragmentation, infrastructure development, poaching, disease, interspecific competition, and climate change (Muller 2018; Brown *et al.* 2021; Muneza *et al.* 2025). The skull hosts some of the most vital parts of the body, such as the brain, sensory organs and the mouth. Therefore, disease, trauma resulting in severe injury, congenital abnormalities and developmental irregularities can have severe consequences for the life of an animal and can adversely affect wildlife populations. Examples of cranial pathologies and their significance for the ecology of wild mammals have been reported for deer (Flueck & Smith-Flueck 2022), hyenas (Van Valkenburgh & White 2021; Kargopoulos *et al.* 2024b), felids (Van Valkenburgh & White 2021), seals (Pertoldi *et al.* 2018), and micromammals (Jentzsch *et al.* 2020) among others. However, relatively little is known about how these factors affect giraffe.

There have been relatively few published studies describing pathological abnormalities and diseases in wild giraffe. Most published reports focus on skin conditions, including giraffe skin disease and papillomatosis, or incidental observations of giraffe included in multi-species die-off records from diseases such as anthrax and rinderpest (e.g., van Dyk *et al.* 2011; Morens *et al.* 2011; Muneza *et al.* 2016; Han *et al.* 2022). Clauss *et al.* (2007) published that the dental wear of wild giraffe aligned with previous published studies (Franz-Odendaal & Kaiser 2003; Franz-Odendaal *et al.* 2004; Bohner *et al.* 2021) being predominantly browsing herbivores compared to grazing herbivores in captivity. Graïc *et al.* (2017) examined the brain of wild (and captive) giraffe, in particular the central nervous system which despite being the largest among terrestrial Cetartiodactyla is highly specialized. Additionally, there have also been reports on skeletal dysplasia (Brown & Wells 2020) and recently Ferguson *et al.* (2023) described observations of suspected congenital and neoplastic cranial deformities in wild giraffe. Even though there are no clear patterns on the frequencies of the reported pathologies in giraffe, some rare cases have only been reported for specific taxa. For example, the cases described in Ferguson *et al.* (2023) only concerned the northern (*G. camelopardalis* (Linnaeus, 1758)) and southern (*G. giraffa* (Boddaert, 1784)) giraffe, with no reported occurrences for Masai (*G. tippelskirchi* Matschie, 1898) or reticulated (*G. reticulata* de Winton, 1899) giraffe. The investigation of the frequency patterns between taxonomic groups is important for the detection of the particular vulnerabilities of each taxon and their significance in a broader context.

The present study reports a range of maxillofacial, dental, and ossicone pathologies and anomalies observed in an extensive dataset of giraffe skulls from the wild and in captivity (Kargopoulos *et al.* 2024a). These observations broaden our knowledge base on cases of potential trauma, disease, and congenital pathologies in wild giraffe and contribute to continued monitoring of threatened populations. We based our study on three null hypotheses: (a) that the frequencies of the total number of pathologies, irregularities, and the main case categories are independent of taxonomy (North/South groups, species, and subspecies), (b) that dental irregularities and periodontitis change through age (as age classes and age groups), and (c) that the occurrence of ossicone bending and fracture is different between males and females due to the necking behaviour of males.

MATERIAL AND METHODS

The studied dataset consisted of 516 skulls of all four *Giraffa* species and their subspecies (Fennessy *et al.* 2016; Winter *et al.* 2018; Petzold & Hassanin 2020; Coimbra *et al.* 2021, 2023; Bertola *et al.* 2024; Kargopoulos *et al.* 2024a;): *Giraffa camelopardalis antiquorum* Jardine, 1835 (n=38), *Giraffa camelopardalis camelopardalis* (Linnaeus, 1758) (n=54), *Giraffa camelopardalis peralta* Thomas, 1898 (n=11), *Giraffa giraffa angolensis* Lydekker, 1903 (n=43), *Giraffa giraffa giraffa* (Boddaert, 1784) (n=121), *Giraffa reticulata reticulata* de Winton, 1899 (n=34), *Giraffa tippelskirchi tippelskirchi* Matschie, 1898 (n=108), and *Giraffa tippelskirchi thornicrofti* Lydekker, 1911 (n=21). The dataset included specimens of both sexes, and spanning all age groups. The South group includes *G. giraffa* and *G. tippelskirchi*, whereas the North group includes *G. reticulata* and *G. camelopardalis*. In a more lumping point of view, these two groups were considered as two species using molecular methods (Hassanin *et al.* 2026). Even though this is a very extensive dataset, technically it cannot be considered random, because of the different ways of acquiring the specimens (legal hunting, zoos, natural death etc.). Skulls from museum collections (n=363; 70.3%), taxidermy companies (originating from the wild; n=82; 15.9%) and conservation areas (opportunistically sampling skulls in natural parks and conservation areas; n=70; 13.6%) throughout Africa were assessed. A comprehensive catalogue of the material, including detailed record of all pathologies found per specimen, is provided in Appendix 1. A summary of the frequencies and relative frequencies of the cases among the different studies groups (taxonomy, age, sex) can be found in Table 1. Pathologies were spotted by visual observations and were investigated based on comparative cases already reported in the literature. Pairwise differences between the relative frequencies of different groups were statistically tested using chi-square with Fisher's exact p-value (which was preferred due to its robustness in small sample sizes; Fu & Arnold 1992) in PAST 5.2 (Hammer *et al.* 2001). This was performed in pairwise comparisons (e.g., males × females) in which a table 2 × 2 is created with one category in one column (e.g., males) and the other in the other column (e.g., females). The first line includes the frequencies (not the relative frequencies) of the pathological cases, and the second line includes the frequencies of the non-pathological cases, using the values in Table 1.

The dental nomenclature of the upper cheek teeth followed both veterinary and zoological nomenclature (Fig. 1). P stands for premolars and M stands for molars. In each case both systems are used for the ease of readers with different backgrounds. Age classes followed Kargopoulos *et al.* (2024a), which is a modified version of the system of Hall-Martin (1976). The age classes range from A to I depending on the estimated age of the individual determined by dental eruption, suture closure and dental wear (Appendix 2). Age classes are organized in four groups: juvenile (age classes A, B), adolescent (age classes C, D), adult (E-G), and old (H, I), to simplify the statistical analysis.

Abbreviations

Institutions

AMNH	American Museum of Natural History, New York;
AMPG	Athens Museum of Palaeontology and Geology, Athens;
DNMNH	Ditsong National Museum of Natural History, Pretoria;
FMNH	Field Museum of Natural History, Chicago;
HNHM	Hungarian Natural History Museum, Budapest;
NCB	Naturalis Biodiversity Center, Leiden;
NHMUK	Natural History Museum of the United Kingdom, London;
NHMZ	Natural History Museum of Zimbabwe, Bulawayo;
NMB	Naturhistorisches Museum Basel;
NMK	National Museums of Kenya, Nairobi;
NMW	Naturhistorisches Museum Wien;
RMCA	Royal Museum of Central Africa, Tervuren;
SAM	Iziko South African Museum, Cape Town;
SMF	Senckenberg Museum Frankfurt;
SMNS	Staatliches Museum für Naturkunde Stuttgart, Stuttgart;
SNM	Slovak National Museum, Bratislava;
UCT	University of Cape Town;
USNM	United States National Museum, Smithsonian Institute, Washington DC;
ZFMK	Zoological Research Museum Alexander Koenig, Bonn;
ZMUA	Zoological Museum, University of Athens, Athens;
ZMB	Museum für Naturkunde, Berlin;
ZSM	Zoologische Staatssammlung, Staatlichen Naturwissenschaftlichen Sammlungen Bayerns, Munich.

Table 1. — Absolute and relative frequencies of dental irregularities, periodontitis, ossicone asymmetry and bending, and surface anomalies per giraffe subspecies, species, north/south, sex, age classes, and age groups. See also: Appendix 3.

	Total	Dental Irregularities		Periodontitis		Ossicones		Surface Anomalies	
G. c. antiquorum Jardine, 1835	38	10	26.3%	9	23.7%	2	5.3%	2	5.3%
G. c. camelopardalis (Linnaeus, 1758)	54	8	14.8%	23	42.6%	5	9.3%	2	3.7%
G. c. peralta Thomas, 1898	11	0	0.0%	3	27.3%	3	27.3%	0	0.0%
G. g. angolensis Lydekker, 1903	43	12	27.9%	17	39.5%	7	16.3%	1	2.3%
G. g. giraffa (Boddaert, 1784)	121	41	33.9%	57	47.1%	15	12.4%	4	3.3%
G. r. reticulata de Winton, 1899	34	10	29.4%	17	50.0%	2	5.9%	0	0.0%
G. t. thornicrofti Matschie, 1898	21	2	9.5%	9	42.9%	1	4.8%	1	4.8%
G. t. tippelskirchi Lydekker, 1911	108	14	13.0%	41	38.0%	6	5.6%	4	3.7%
G. camelopardalis (Linnaeus, 1758)	115	20	17.4%	40	34.8%	12	10.4%	5	4.3%
G. giraffa (Boddaert, 1784)	179	70	39.1%	78	43.6%	23	12.8%	5	2.8%
G. reticulata de Winton, 1899	34	10	29.4%	17	50.0%	2	5.9%	0	0.0%
G. tippelskirchi Matschie, 1898	129	16	12.4%	50	38.8%	7	5.4%	5	3.9%
North	149	28	18.8%	57	38.3 %	14	9.4%	5	3.4%
South	293	79	27.0%	128	43.7 %	30	10.2%	10	3.4%
Males	331	74	22.4%	140	42.3%	44	13.3%	14	4.2%
Females	162	39	24.1%	66	40.7%	5	3.1%	2	1.2%
Age Class A	33	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Age Class B	45	0	0.0%	0	0.0%	0	0.0%	1	2.2%
Age Class C	18	3	16.7%	6	33.3%	0	0.0%	0	0.0%
Age Class D	40	9	22.5%	8	20.0%	0	0.0%	1	2.5%
Age Class E	123	44	35.8%	43	35.0%	19	15.4%	2	1.6%
Age Class F	110	38	34.5%	64	58.2%	16	14.5%	3	2.7%
Age Class G	43	9	20.9%	30	69.8%	6	14.0%	2	4.7%
Age Class H	18	3	16.7%	14	77.8%	3	16.7%	0	0.0%
Age Class I	16	2	12.5%	14	87.5%	1	6.3%	1	6.3%
Juvenile	78	0	0.0%	0	0.0%	0	0.0%	1	1.3%
Adolescent	58	12	20.7%	14	24.1%	0	0.0%	1	1.7%
Adult	276	92	33.3%	137	49.6%	41	14.9%	6	2.2%
Old	34	5	14.7%	28	82.4%	4	11.8%	2	5.9%

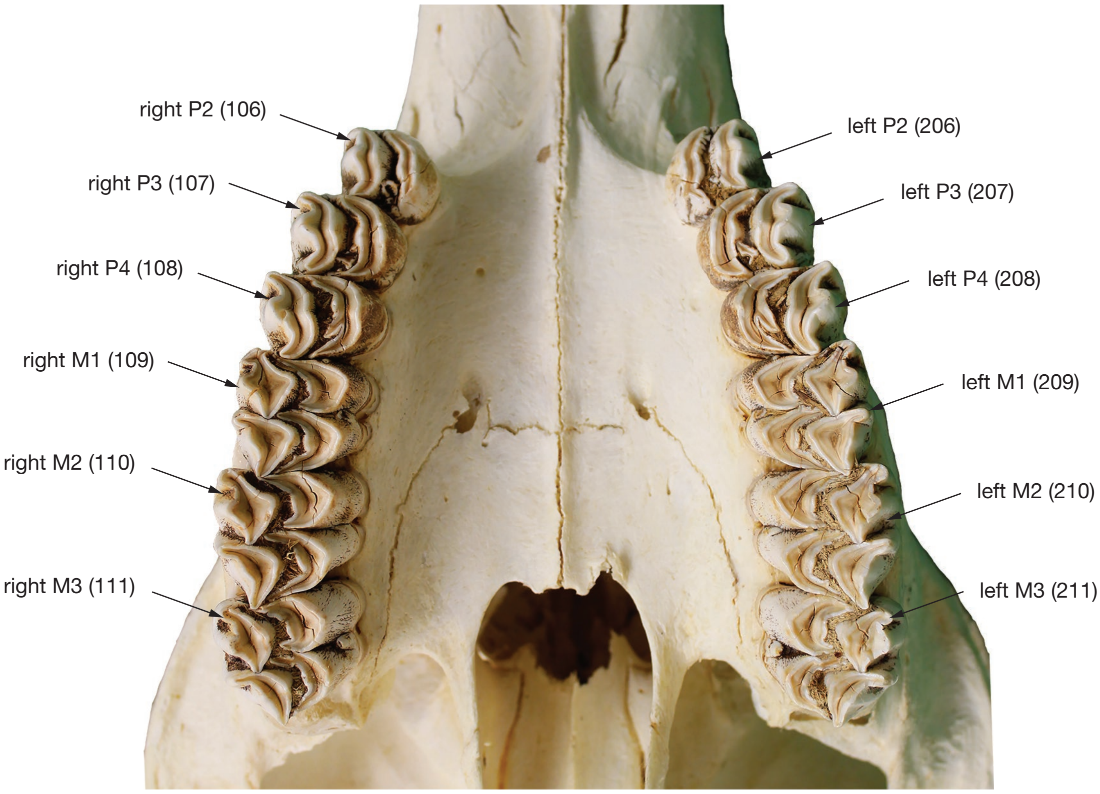

Fig. 1. — Dental nomenclature followed in this study (FMNH-236496, *G. g. giraffa* (Boddaert, 1784), male, age class E, South Africa). Abbreviations: **P**, premolars; **M**, molars.

Natural Parks

CHA-ZAK	Zakouma, Chad;
KEN-AMB	Amboseli NP, Kenya;
KEN-MAM	Maasai Mara NP, Kenya;
KEN-MER	Meru, Kenya;
KEN-MGE	Mgeno Conservancy, Kenya;
KEN-RUM	Ruma NP, Kenya;
KEN-TSE	Tsavo East NP, Kenya;
KEN-TSW	Tsavo West, Kenya;
NAM-ETH	Etosha Heights Private Reserve, Namibia;
NAM-HOA	Hoanib River System, Namibia;
NER-KOU	Kouré Giraffe Reserve, Niger;
UGA-MUR	Murchison Falls, Uganda;
ZAM-LUA	Luangwa Valley, Zambia.

Taxidermy Collections

NAM-ING	Ingwe, Namibia;
NAM-NYA	Nyati, Namibia;
NAM-TAU	Tau, Namibia;
SA-SI	Splitting Image, South Africa;
ZIM-TCI	Trophy Consultants International, Zimbabwe.

RESULTS

Dental irregularities

109 out of the 516 specimens in the dataset exhibited deviations from the standard dental morphology. These deviations included total absence of teeth, alternations in the orientation of one or more teeth, differences in cusp morphology (including the presence/absence of cusps), irregular dental wear patterns, and fractures. These variations are described in detail below.

Absence of teeth

This relatively rare phenomenon was observed only three times in our sample: twice for P2 (106) (in NHMUK-ZD-1902.11.13.2, *G. c. camelopardalis*, male, age class F, South Sudan, Fig. 2A; and in NHMW-5575, *G. camelopardalis* subsp., male, age class G, Sudan) and once for M3 (bilaterally 111 and 211) (SMNS-Z-MAM-45425, *Giraffa* sp., female, age class F, Zoo Wilhelma, Fig. 2B). In both cases the surface of the maxilla where the tooth was missing appeared faintly rugose, but did not show any signs of trauma (e.g., breakage, secondary ossification, or any sign of healing). This suggests that the teeth were not lost, but likely never erupted.

Misaligned teeth

Several cases of teeth that were rotated in the maxilla were observed. In these specimens the teeth were not perfectly aligned on a smooth arch but showed positioning deviations. In most cases, only one tooth was aberrant, but occasionally multiple teeth were affected. Single-tooth deviations were seen in the P2 (106/206) (n=5), P3 (107/207) (n=2), P4 (108/208) (n=3), and M3 (111/211) (n=3; Fig. 2C), while deviations in more than one tooth were seen in three specimens. In NHMUK-ZD-1873.8.29.7 (*G. c. camelopardalis*, female, age class E, Ethiopia) only the premolars were affected, whereas in NHMW-974 (*G. t. tippelskirchi*, female, age class G, Kenya) both the molars and the premolars were affected to a considerable degree. In the latter specimen the P4 (108) was lost (Fig. 2D), but it was not possible to ascertain whether the two irregularities were related.

Irregular dental wear

Nine specimens showed uncommon dental wear patterns. In six instances, a single maxillary cheek tooth was considerably worn more than the others of the toothrow. In these cases, this tooth was also much more worn than in other specimens of the same age class. In particular, this was observed on the P2 (206) (ZIM-TCI-181a, *G. g. giraffa*, male, age class E, Zimbabwe), the P3 (207) (FMNH-34425, *G. g. giraffa*, male, age class G, Botswana), the P4 (208) (ZIM-TCI-472, *G. g. giraffa*, male, age class E, Zimbabwe), and the M1 (109/209) (n=4) (Fig. 2E). Additionally, three individuals showed deviations in the dental wear of only parts of specific teeth. RMCA-RG-3748 (*G. c. antiquorum*, female, age class E, D. R. Congo) showed an early dentine connection between the lingual and the buccal cusps, which is unusual considering the dental wear stage shown on the other teeth. Finally, ZSM-1911-2446 (*G. t. tippelskirchi*, female, age class F, Tanzania) and USNM-304613 (*G. r. reticulata*, male, age class F, Washington Zoo) showed an irregular wear pattern on the left M1 (209), with the distal half worn more than the mesial one (Fig. 2F). While this was more evident on the left side of the skull, the right M1 (109) also showed a milder version of such irregular wear pattern. In general, six specimens showed such deviations on the left side of the maxilla, two on the right, and just one on both sides.

Irregular dental morphology

Common dental irregularities observed in the sample related to the morphological range of the cusps of the upper cheek teeth. This rarely involved the premolars, with n=3 for P2 (106/206) (with unusual cristae in two specimens and an additional lingual cusp-like structure in FMNH-32901, *G. r. reticulata*, female, adult, Ethiopia; Fig. 3A), and two specimens for P3 (107/207) (USNM-162018, male, age class F, Kenya, as well as FMNH-32901). The specimen FMNH-32901 also had an additional P4 (108/208) cusp-like structure on both sides of the maxilla (Fig. 3A). Two more specimens showed irregular morphology of the P4 cristae (SI 1). Three specimens presented uncommon morphology on the M1 (109/209) and one on the M2 (110/210) (SMNS-Z-MAM-45425, *Giraffa* sp., female, age class F, Zoo Wilhelma; Fig. 2B). On the M1, AMNH-M-53549 (*G. c. antiquorum*, female, age class D, D. R. Congo; Fig. 3B) retained a barrier between the mesostyle and the metacone, RMCA-RG-3749 (*G. c. antiquorum*, female, age class E, D. R. Congo) had a double crista only on the left M1 (209), while ZIM-TCI-X3 (*G. g. giraffa*, male, age class F, Zimbabwe; Fig. 3C) had a lingually expanded protocone. Interestingly, the M3 (111/211) was the most commonly affected tooth. There were four cases in which this tooth had a rather peculiar morphology that differed markedly from the standard phenotype. Possibly the most extreme case is evident in specimen SMNS-Z-MAM-49722 (*Giraffa* sp., female, age class I, Wilhelma Zoo), in which the left M3 (211) was

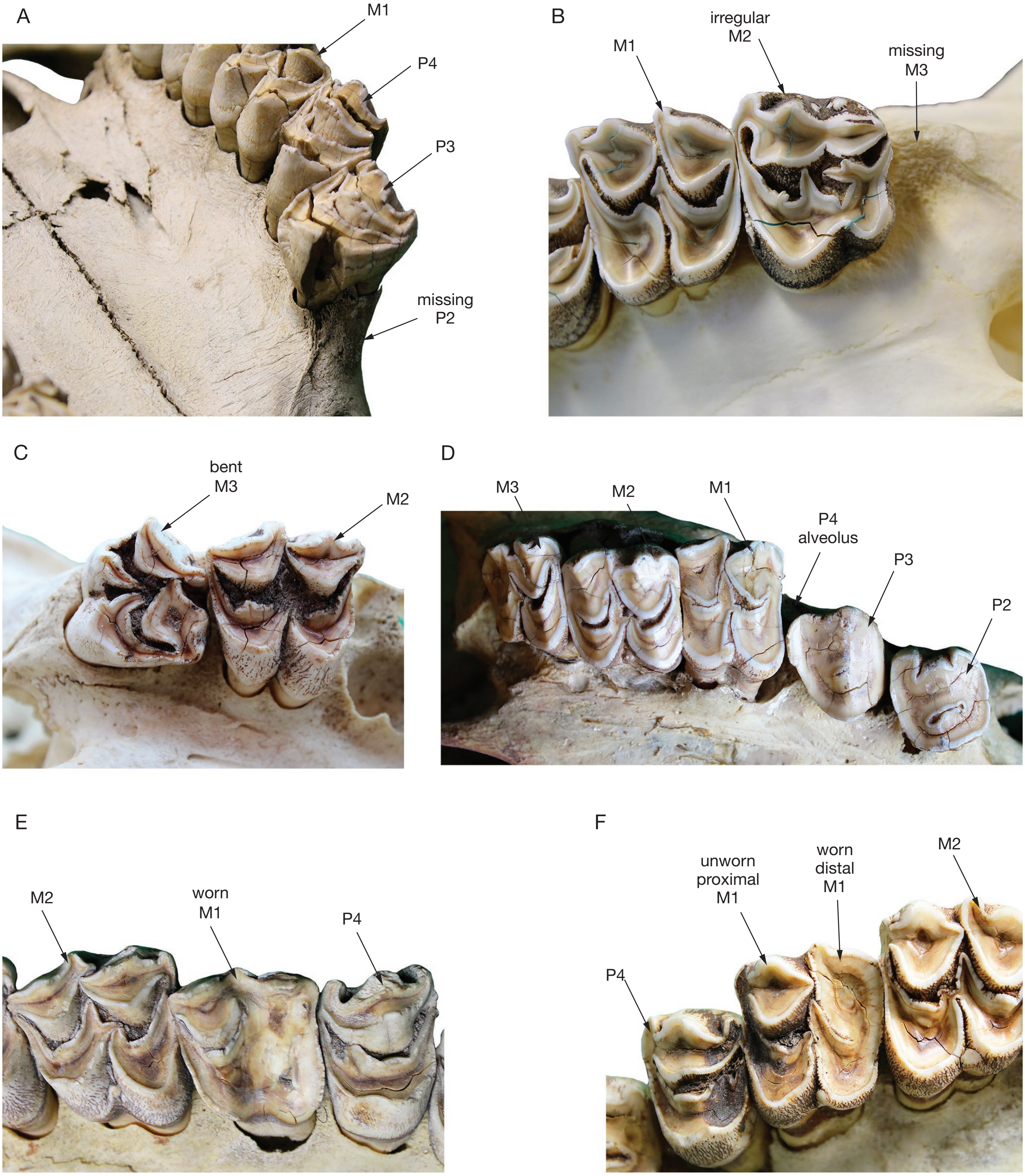

Fig. 2. — Cases of dental irregularities: **A**, NHMUK-ZD-1902.11.13.2, left upper cheek teeth in proximoventral view showing the missing P2 (106); **B**, SMNS-Z-MAM-45425, left upper cheek teeth in ventral view showing the missing M3 (211); **C**, ZIM-TCI-291, right upper cheek teeth in ventral view showing the misaligned M3 (111); **D**, NHMW-974, right upper cheek teeth in ventral view showing the misaligned molars and absent P4 (108); **E**, NHMUK-ZD-1898.7.2.5, right upper cheek teeth in ventral view showing the extreme wear on M1 (109) in comparison to the other cheek teeth; **F**, ZSM-1911/2446, left upper cheek teeth in ventral view showing the extreme wear on the distal half of the M1 (209) in contrast to the wear on its mesial half.

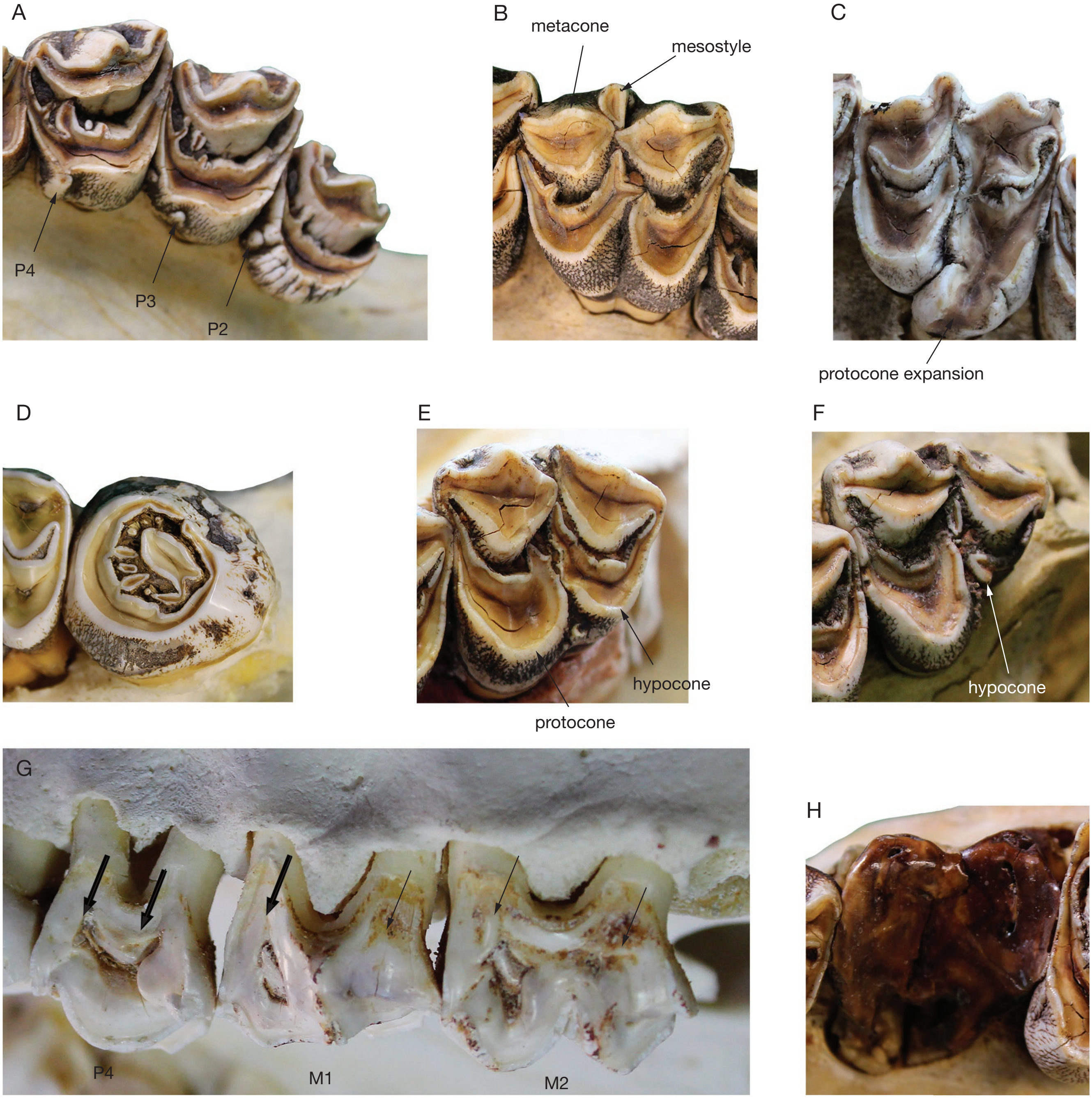

Fig. 3. — Additional cases of dental irregularities: **A**, FMNH-32901, upper right cheek teeth in ventral view showing the additional lingual cusp-like structures on right P2-P4 (106-108); **B**, AMNH-M-53549, right M1 (109) in ventral view showing the absence of dentine connection between the metastyle and the metacone; **C**, ZIM-TCI-X3, right M1 (109) in ventral view showing the irregularly lingually expanded protocone; **D**, SMNS-Z-MAM-49722, left M3 (211) in ventral view showing a uniquely circular shape with faint cusps and cristae; **E**, RMCA-RG-3710, left M3 (211) in ventral view showing the reduced size of the hypocone in relation to that of the protocone; **F**, NHMUK-ZD-1931.2.1.48, left M3 (211) in ventral view showing the vestigial/practically absent hypocone; **G**, NAM-NYA-3, left upper cheek teeth (P4–M2; 208-210) in buccal view exhibiting damaged and healed buccal walls; and **H**, USNM-163324, left M1 (209) in ventral view exhibiting clear signs of decay.

rounded, enlarged and with just faint signs of its cristae and cusps (Fig. 3D). The most frequently observed irregularity was the reduction of the hypocone. In 56 specimens the M3 (111/211) hypocone was reduced in size, having approximately half the size of the protocone (Fig. 3E). In 12 other specimens, the hypocone was vestigial or nearly absent (Fig. 3F). In total, 68 specimens (13.2%) showed a reduced M3 hypocone.

Additional dental irregularities

In addition to the aforementioned dental deviations, some other dental irregularities were observed. Specimen NHMZ-20382 (*G. t. thornicrofti*, male, age class E, Zambia) exhibited a diastema between the left P2 (206) and P3 (207), which was not present in any of the other studied specimens. Ten specimens showed evidence of broken molars with a smooth surface

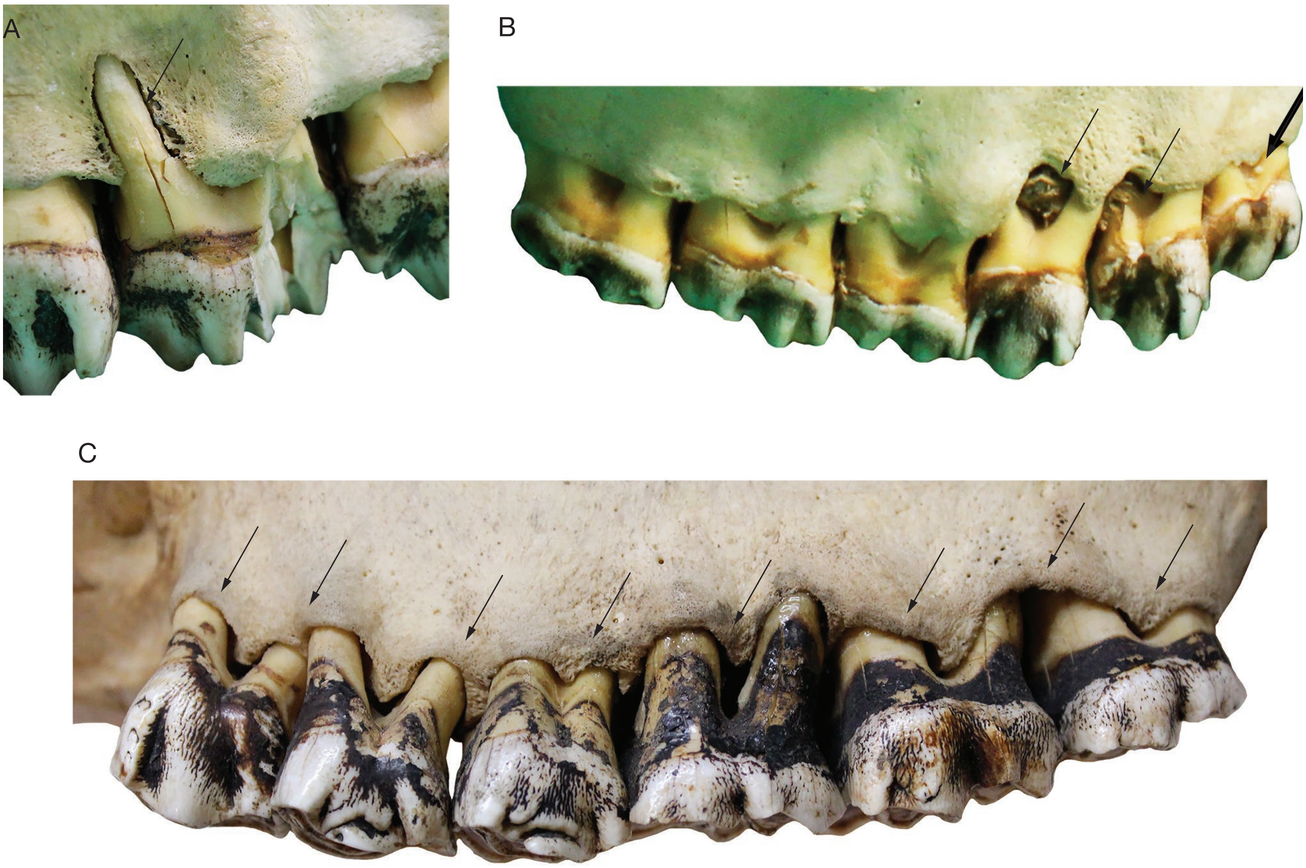

Fig. 4. — Cases of maxillary erosions: **A**, FMNH-32901, right M1 (109) in buccal view with maxillary erosion exposing its distobuccal root; **B**, USNM-304612, right upper cheek teeth in buccal view with maxillary erosions exposing roots of the premolars; **C**, RMCA-RG-6343, left upper cheek teeth in buccal view with maxillary erosions exposing roots, paired with broken teeth and extreme dental wear.

indicating further use after the breakage (e.g., NAM-NYA-3, *G. g. angolensis*, male, age class F, Namibia; NHMZ-26178, *G. g. giraffa*, male, age class F, Zimbabwe) (Fig. 3G). In two female specimens of *G. t. tippelskirchi* (ZSM-1911-2446, age class F, Tanzania; NHMW-974, age class G, Kenya) only the right P4 (108) was lost due to localized malformations or deformations of the maxilla. In addition, three skulls (NHMW-5575, *G. camelopardalis* subsp., male, age class G, Sudan; NAM-TAU-32, *G. g. angolensis*, male, age class F, Namibia; USNM-163324, *G. r. reticulata*, female, age class G, Kenya) showed discoloured molars that likely underlie severe tooth decay (Fig. 3H).

Cranial irregularities

Numerous deviations from the 'normal' cranial anatomy were observed in the dataset. These included maxillary erosions, asymmetrical ossicones, evidence of periosteal growth likely associated with male necking behaviour and/or trauma, congenital malformations, and possible neoplasia.

Maxillary erosions

The most commonly observed pathology was focal erosions of the maxillary alveolar bone, identified in varying stages across 206 specimens (39.9% of the total sample). The affected area appeared pitted, and gradually deteriorated, revealing the alveolar cavities and exposed tooth roots. This was more evident on the buccal aspect of the maxilla, but also observed on the lingual aspect, within the alveoli, and also between the alveoli. These erosions typically affected multiple maxillary teeth, however, in some cases only one tooth was affected. In particular, single-tooth erosions were observed in P2 (106/206) (n=11), P3 (107) (n=1), P4 (108/208) (n=5), M1 (109/209) (n=31), M2 (110/210) (n=6), and M3 (110/210) (n=3) (Fig. 4A). The erosions were confined to the premolars in some specimens (Fig. 4B), while in others they were restricted to the molars. Even more frequently, usually in individuals of relatively old age, the erosions were extended and affected most of the teeth (n=109; 21.1%). In some specimens of old age this was also linked to extreme dental wear, exposed dental cavities and broken teeth (Fig. 4C). Finally, there were many specimens that did not retain any teeth. Judging from the morphology of the remaining alveolar surfaces, this may have been caused (at least in part) by bone decay undermining the implantation of the teeth in the maxilla.

Ossicone asymmetry

Many giraffe skulls showed signs of asymmetry in terms of ossicone size and orientation. Sixteen specimens showed shorter left ossicones, whereas 21 specimens showed shorter right

Fig. 5. — Examples of ossicone asymmetry: **A**, unilateral ossicone asymmetry in dimensions – shorter and narrower left ossicone with no distinct terminal end, RMCA-RG-767 (*G. camelopardalis* subsp., male, age class E, South Sudan); **B**, unilateral ossicone asymmetry in orientation – the left ossicone is more upright than the right one, ZSM-1911-2443 (*G. c. camelopardalis* (Linnaeus, 1758), male, age class F, Kenya). Scale bars: 5 cm.

ossicones (Fig. 5A). Such height difference was also linked to differences in diameter and rugosity. Different shapes of the terminal end of the ossicones were observed, some narrowing towards the tip and not displaying the widening or bulging as seen in most cases. Additionally, four specimens showed signs of bilateral bending of the ossicones, with both facing towards the same direction. However, the same morphology was also seen unilaterally in eleven specimens, in which only one of the ossicones deviated from its standard angle (Fig. 5B).

Potential Trauma

Multiple specimens showed signs of non-aggressive periosteal reactive growth which may be related to trauma. Such exostoses were often distributed across areas that may have been impacted by fighting or necking behaviour, i.e. predominantly the ossicone(s), over the dorsal aspect of the orbits, and over the frontal bones. Three specimens (NHMZ-29112, *G. g. giraffa*, male, age class G, Botswana; ZSM-1914-1325, *G. t. tippelskirchi*, male, age class I, Tanzania; ZMB-MAM-17381, *G. t. tippelskirchi*, male, age class I, Tanzania; Fig. 6A, B) also had fenestrations surrounded by severe periosteal reactive bone growth. In addition, multiple specimens showed fractured ossicones with the majority being male (n=10) versus female (n=3) (Fig. 6C, D).

One specimen (NHMUK-ZD-1938.7.8.22, *G. c. antiquorum*, male, age class F, Cameroon; Fig. 6E, F) showed distinct signs of trauma, such as erosion and remodification on the left half of the distal part of the skull. Lesions were observed on the temporal bone, the paraoccipital and the mastoid/paracondylar processes, and along the left part of the nuchal crest, ending in an enlarged nuchal hill, which was much larger than that on the right. Secondary ossification was evident on the nuchal crest and the temporal bone. No further pathological evidence were seen on the ossicones or any other part of the cranium. An additional seven specimens showed signs of secondary ossification, periosteal reactions, or lesions in different parts of the skull.

Congenital abnormalities

Four potential cases of congenital abnormalities were observed in the dataset. A male skull displayed a moderate left lateral deviation of the nasal bones, most consistent with a condition known as *campylorrhinus lateralis* or wry nose (ZSM-1914-0127, *G. t. tippelskirchi*, male, age class E; Fig. 7A, B). Another skull belonged to a male giraffe, recently deceased from natural predation, that had a severe incomplete fusing of the nasal and frontal bones consistent with a midfacial cleft palate (Fig. 7C-D). The skull exhibited severe damage from predation and local climate, making it unclear whether the defect also extended to the palatine bones of the oral cavity. A noticeable groove over the parietal bones ended between the ossicones, whilst the left ossicone was notably shorter than the right one.

Two specimens (RMCA-RG-25673, *G. c. antiquorum*, male, age class E, D. R. Congo, Fig. 7E; NHMW-5483, *Giraffa* sp., female, age class D, Schonbrun Zoo, born in Kenya, Fig. 7F) show bilateral longitudinal fistulae in the nasal bones. In RMCA-RG-25673 these fistulae were situated near the mesial end of the nasal bones, whereas in NHMW-5483 they were located more distally, in the middle part of the bone. While present on both sides, they were not perfectly symmetrical in terms of length, width, and position. In the

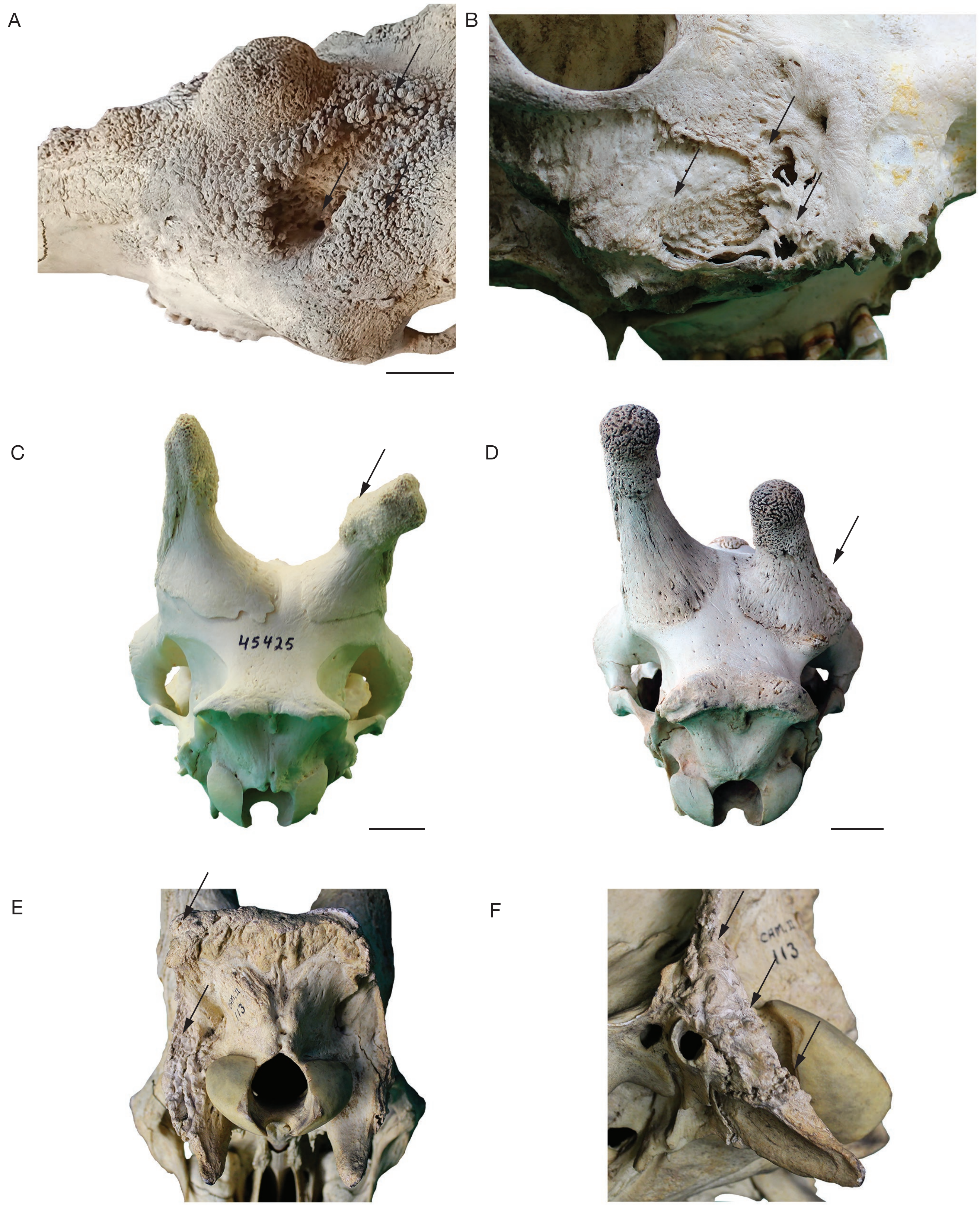

Fig. 6. — Cases of trauma: **A**, ZMB-MAM-17381 in dorsolateral view showing the presence of periosteal lesions on the dorsal surface of the skull; **B**, ZSM-1914-1325 in lateral view showing periosteal lesions on the right maxilla; **C**, SMNS-Z-MAM-45425 in caudal view showing the fracture on the right ossicone; **D**, ZIM-TCI-089 in caudal view showing the fracture on the right ossicone; **E**, **F**, NHMUK-ZD-1938.7.8.22 showing evidence of trauma on the left part of the nuchal crest and on the left temporal bone caudally to the external acoustic meatus: **E**, caudal view of the skull showing the difference between the left and right nuchal crest and temporal bones; **F**, left temporal bone in lateral view showing the extent of the trauma caudally to the external acoustic meatus towards the paraoccipital process. Scale bars: 5 cm. B, E, F, not to scale.

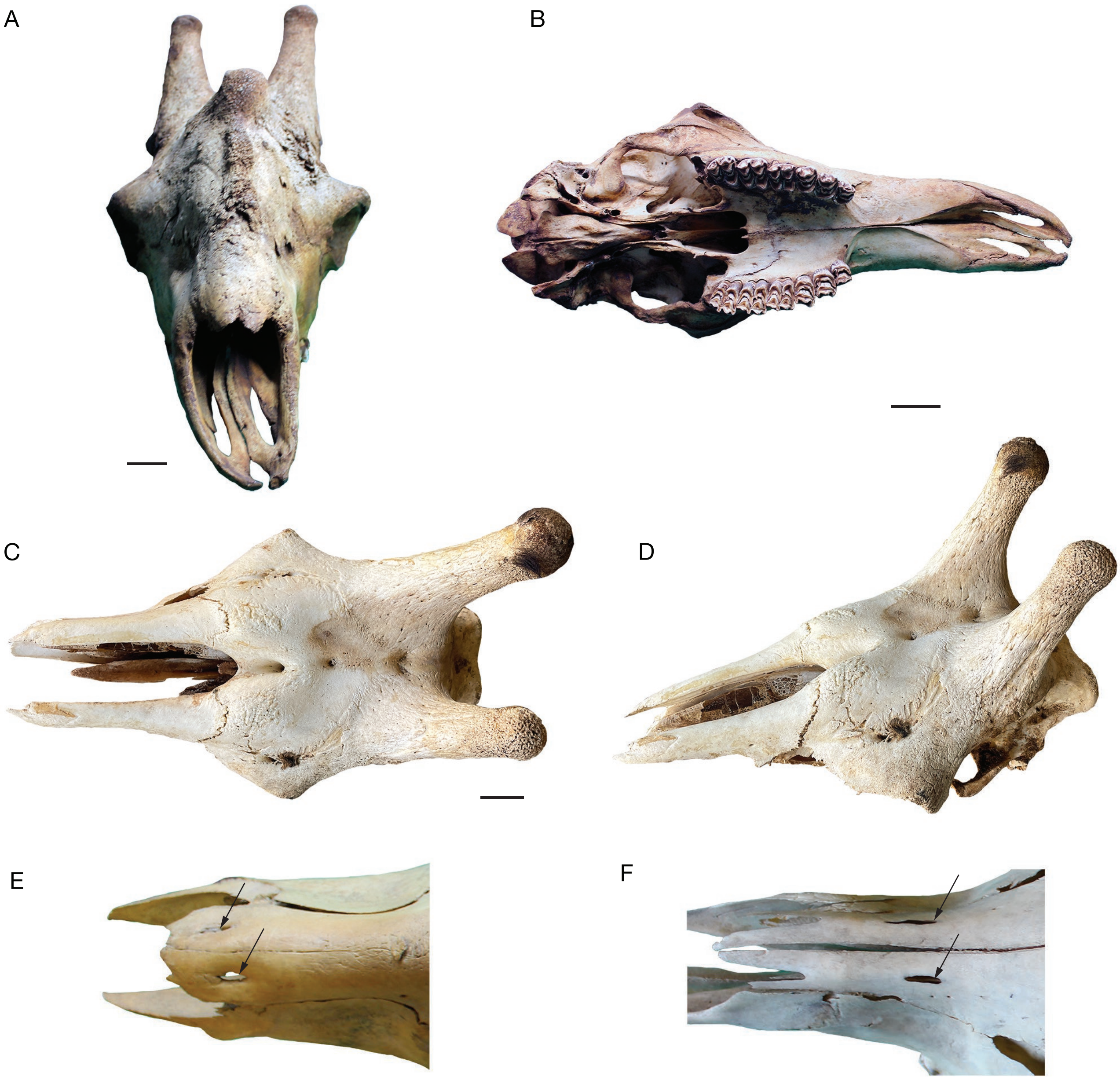

Fig. 7. — Cases of wry nose (**A**, **B**), cleft palate (**C**, **D**), and nasal fistulae (**E**, **F**): **A**, ZSM-1914-0127 showing wry nose in mesial view; **B**, ZSM-1914-0127 showing wry nose in ventral view; **C**, NAM-HOA-1 showing cleft palate in dorsal view, NAM-HOA-1 showing cleft palate in dorsolateral view; **E**, RMCA-RG-25673 showing nasal fistulae in dorsal view; **F**, NHMW-5483 showing nasal fistulae in dorsal view. Scale bars: 5 cm. E, F, not to scale.

Kordofan specimen the borders of the piercings were faintly covered by secondary bone, whereas in NHMW-5483 the borders retained the same form as the surrounding bone. These fistulae likely developed congenitally as there was no evidence of healing or bone remodelling to suggest a traumatic origin. However, their origin could not be determined without histological evaluation.

Neoplasia

One skull showed signs consistent with malignant bone alterations likely indicative of a neoplastic process. NHMZ-22635 (*G. t. thornicrofti*, male, adult, Zambia; Fig. 8) had severe bone growth on the right part of the skull from the orbit to the ossicone. The right ossicone was ventrally and laterally deviated from the midline, while its base was noticeably thickened and irregular as compared to the left ossicone. Periosteal reactive growths were evident on the left side, most notably over the left orbit. Still, these changes were more consistent with exostoses resulting from trauma caused by aggression between males. The specimen included the mandible, and the right ramus appeared 'moth-eaten' in some areas. Although suggestive of neoplasia, histopathologic investigation is needed to confirm this diagnosis.

DISCUSSION

Comparison of the deviant anatomical features of the giraffe skulls to previously reported cases, especially in ruminants, but also in various other mammals enabled preliminary diagnoses of the pathologies. In some cases, these pathologies were caused by congenital malformations, whereas others were related to injuries or disease.

Dental irregularities

We proposed that genetic or developmental anomalies resulted in the two cases of teeth being absent, since there is no direct evidence of healed trauma or post-mortem removal. Such incidents are often termed hypodontia (a type of dental agenesis) and are known to have a genetic origin (e.g., Nieminen 2009). Similar cases have been seen in other mammals, such as in felids (Verstraete *et al.* 1996), dogs (Axenovich *et al.* 2004), rodents (Satokata & Maas 1994), horses (Giavitto & Meehan 202ł0), as well as among humans (e.g., Al-Ani *et al.* 2017, and references therein). Loss of teeth can be linked with periodontitis, but since the studied specimens did not show advanced stages of periodontitis or abundance of blood vessels around the position of the missing tooth, this cause is not considered possible (Evenhuis *et al.* 2022).

Misaligned teeth as we have reported in the giraffe, are also known in primates (Mills 1963), rodents, and lagomorphs (Verstraete 2003; Legendre 2018). Such cases can be caused by anchylosis or traumatic loss of a deciduous tooth and irregular facial bone growth (e.g., Leighton 1991, and references therein). Within a dataset of more than 500 specimens, it was expected to find some individuals with missing or misaligned teeth based on the previously published literature.

The irregular dental morphology that we observed in some giraffe teeth, not unexpected in low frequences, has been observed in several other ruminants (e.g., Fortelius 1985). The extremely irregular morphology of the specimen SMNS-Z-MAM-49722 (Fig. 3D) could be associated with poor nutrition or more likely with genetic abnormalities that led to a deviant development (e.g., Dixon & Vlaminck 2022). The occurrence of broken teeth is common in animals that feed on hard material, such as hyenas (Van Valkenburgh 1988; Kargopoulos *et al.* 2024b), but not very common in ruminants. The dental breakages observed may have been the result of intrasexual aggression, often resulting in injuries, or even perhaps from the mastication of bones and soil, which, although unusual, is observed in giraffe (Shorrocks 2016).

Interestingly, incidences of missing teeth among specimens tend to be focused either on the first or the last cheek teeth, which are often also the most commonly misaligned ones. It is likely that this reflects the low significance of these teeth in mastication: in other mammalian taxa, the most mesial or distal cheek teeth are often found to be more variable than the central cheek teeth (Hall 1940; Gisburne & Feldhamer 2005; Natsume *et al.* 2008; Kargopoulos *et al.* 2023) which has been interpreted as an indication of selective relaxation. It is likely that the central cheek teeth play a more crucial role in mastication than the terminal cheek teeth. For ruminants this is also supported by the findings of Natsume *et al.* (2008) and aligns with the eruption order reported by Hall-Martin (1976). Consequently, there might be a greater evolutionary pressure to a stable morphology for these mid-positioned cheek teeth. Through the Probable Mutation Effect (PME), relaxed selective pressure allows mutations to flourish on the genes responsible for developing the respective structures (Brace 1964; Byles 1972). For example, PME is thought to explain the evolution of size in human teeth (Calcagno & Gibson 1988), fossil hyaenid dentition (Kargopoulos *et al.* 2023), sloth and tragulid bony labyrinth (Billet *et al.* 2012; Mennecart & Costeur 2016), primate metacarpal length (Tague 2002), and eye morphology in cave fish (Wilkens 1988).

Deviations from the normal patterns of tooth morphology and dental wear can impact the survival and well-being of wild ruminants, since the loss of dental functionality can lead to starvation and ultimately death (Lucas 2004). Nevertheless, irregularities in dental wear have been reported in several ruminant species, potentially affected by the dietary contents of particular cases, e.g., as seen in 12 species of bovids and cervids by Jurado *et al.* (2008), as well as in the teeth of various herbivores at the Pliocene fossil locality of Langebaanweg in South Africa, including high prevalence of hypoplasia among the giraffids (Franz-Odendaal *et al.* 2004). In the current study we found unique irregular dental wear in giraffe, with only specific teeth found to have extreme wear in comparison to the rest of the dentition (Fig. 2E) or even specific parts of one tooth were found to be extremely worn (Fig. 2F). We found such patterns in both wild and captive giraffe, indicating that they are not exclusively a result of captivity conditions. While the cause for these irregularities is unknown, we hypothesize that it is most likely related to jaw mechanics and specific behavioral traits. For example, the consumption of preferred *Vachellia* and *Senegalia* leaves often results in the accidental consumption of thorns, which in turn can cause small oral injuries. Depending on the severity of such injuries, individuals may be forced to move their jaws in a repetitive, particularly, and possibly irregular manner, eventually leading to more evident dental wear on particular regions of the toothrow.

Cranial irregularities

Since all studied specimens were either government or private property, it was not possible to obtain histopathologic bone samples. Thus, we cannot be certain regarding the cause of the disorders.

Maxillary erosions

The maxillary erosions were observed in 206 specimens (39.9%) and in an extended stage in 109 (21.1%). They were developed around the alveoli, gradually exposing dental roots and eventually resulted in teeth loss. The morphology of the affected areas was visually consistent with periodontitis, a common disease in many mammalian taxa, including canids, mustelids, seals, hyenas, hedgehogs, livestock, and deer (Verstraete 2003; Govender *et al.* 2011; Albuquerque *et al.* 2012; Azorit *et al.* 2012; Borsanelli *et al.* 2018; Evenhuis *et al.* 2022; Kargopoulos *et al.* 2024b). Initially, periodontitis

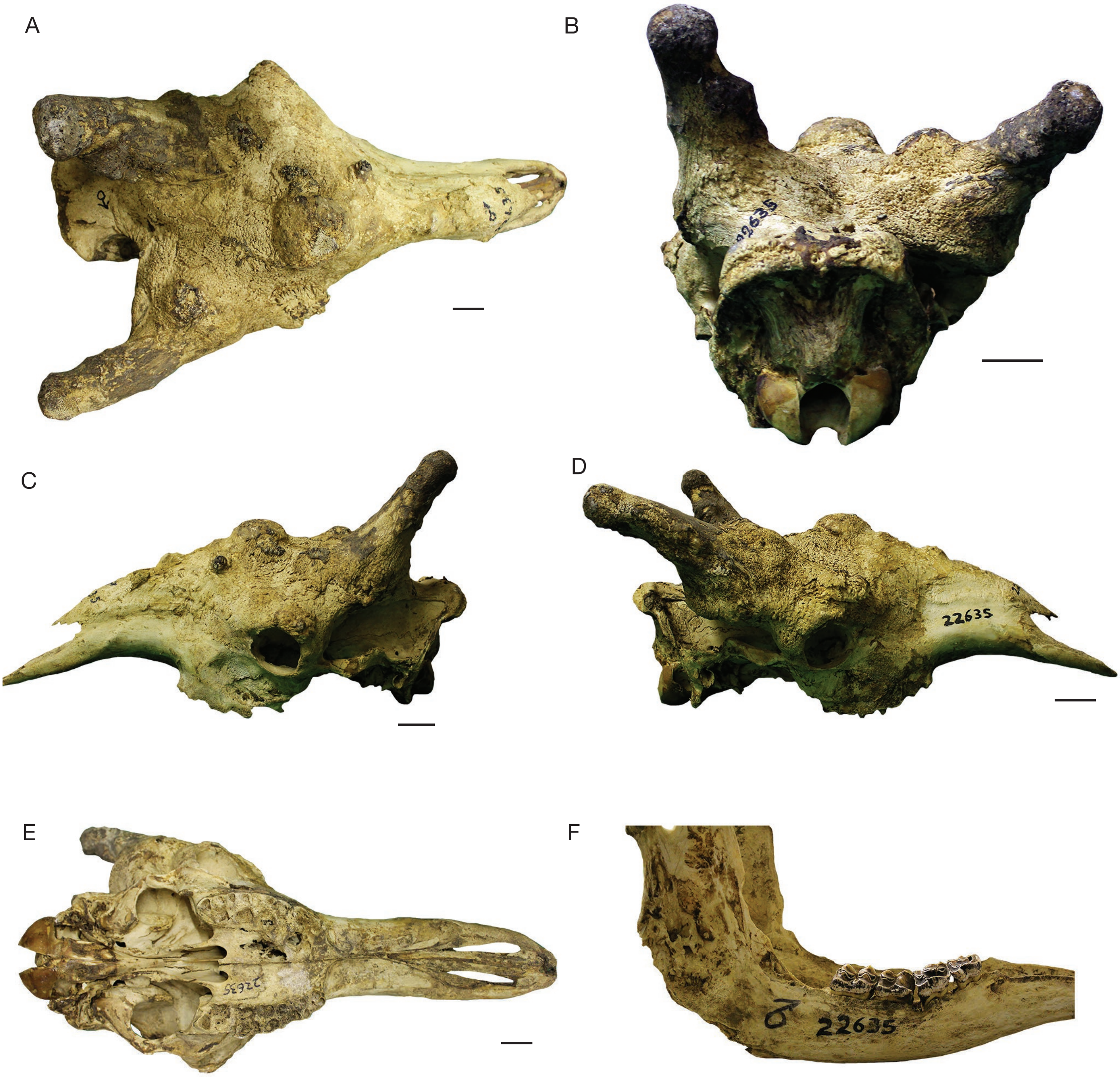

Fig. 8. — Specimen NHMZ-22635 (*G. t. thornicrofti* Lydekker, 1911, male, adult, Zambia) showing marked signs of neoplasia in **A**, dorsal, **B**, caudal, **C**, lateral-left, **D**, lateral-right, **E**, ventral, and **F**, mandibular lateral-right views. Scale bars: 5 cm. F, not to scale.

appears through accumulated plaque on the teeth, which is then infected with bacteria (Walli & Holcombe 2020). The bacterial activity around the teeth results in the recession of the alveolar margin, inflammation, and bone remodelling such as bone resorption, pitting, and reactive bone formation (Neville *et al.* 2002; Albuquerque *et al.* 2012).

A giraffe's diet includes a wide variety of plant food sources. *Vachellia* and *Senegalia* spp. are often the predominant dietary preference, even though seasonal availability leads to the selection of other options (Dagg 1971, 2014; Krumbiegel 1971; Shorrocks 2016; and references therein). Even though the carbohydrate/sugar contents of preferred *Vachellia* and *Senegalia* leaves are relatively low (Mokoboki *et al.* 2005; Khanyile *et al.* 2014; Kheloufi *et al.* 2019), the quantities consumed could lead to the development of plaque that acts as a physical setting for the growth of bacteria. *Vachellia* and *Senegalia* also have a variety of thorns, and some have a symbiotic relationship with ants as a defence against browsing, even though the latter is not seen in most of the plants foraged by giraffe (e.g., Goheen & Palmer 2010; Martins 2010). Therefore, it is possible that the thorns might cause oral scratches, which could potentially act as a way of spreading the disease into the maxilla.

Given the very high frequency of maxillary erosions in giraffe, it can be deduced that at least at an early stage they

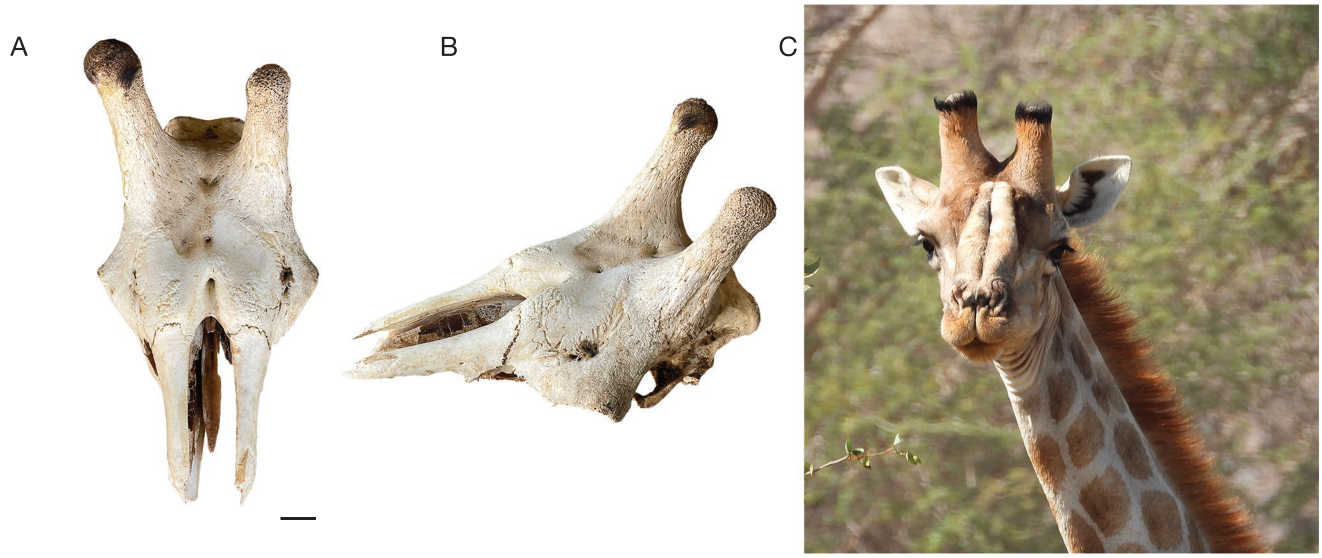

Fig. 9. — The case of cleft palate (NAM-HOA-1) showing the skull in dorsal (**A**) and dorsolateral (**B**) views, as well as a picture of the individual from northwest Namibia while it was still alive (**C**). Scale bar: 5 cm.

do not cause significant problems in the mastication. However, advanced stages that are usually combined with dental loss would definitely affect the ability of the giraffe to chew properly and maintain digestion. Note that in the current study, mandibles were very rarely studied. Such pathologies may also affect the lower teeth and the mandibular corpus, with further evaluation required.

Ossicone asymmetry

Several specimens (n=37) displayed ossicone asymmetry through either shortening of the left or right ossicone or showed a deviation of one ossicone from midline. However, most cases involved unilateral shortening of one ossicone, likely related to congenital development or potentially could be evidence of fluctuating asymmetry, which refers to the random, non-directional deviation from bilateral symmetry, possibly resulting from an organism undergoing environmental or genetic stress (Palmer 1994; von Hardenberg *et al.* 2004). Fluctuating asymmetry has been seen in various wild ruminant species (Bowyer *et al.* 2001; Côté & Festa-Bianchet 2001; Chirichella *et al.* 2020). Other potential causes for ossicone asymmetry could have resulted from trauma caused by necking or fighting among males.

Potential trauma

Male giraffe engage in intraspecific aggression (necking) which generally involves the use of their necks and heads to assert dominance, starting in early adulthood (Pratt & Anderson 1982, 1985; Brand 2007). Over their lifetime, bull giraffe engage in fights, and it is therefore reasonable to propose that the increased areas of periosteal bone growth over the various aspects of the skull and ossicones observed in this study can be linked to trauma from necking and fighting behaviour.

Periosteal reactive growth consists of the periosteal deposition of bone that results in an over-growth on its outer surface (Allen *et al.* 2022). Four cases of completely fractured ossicones were observed in our analysis. For the two males this could very well be a potential result of fighting behaviour, but the underlying cause is less clear for the two female specimens. Female giraffe are less likely to engage in fighting behaviour (Simmons & Scheepers 1996), yet such trauma might be a result of an accident or defence or getting caught in a tree or other obstacle. Additionally, female ossicones are far narrower and more fragile than those of the males, making them more susceptible to fractures. All cases of potential trauma showed nonaggressive bone formation and uncomplicated fracture healing. However, other causes such as infection, neoplasia, or congenital malformations cannot be entirely ruled out.

Congenital abnormalities and Neoplasia

Congenital abnormalities and incidences of neoplasia are poorly documented in wild giraffe (Ferguson *et al.* 2023) and rare in zoo giraffe (Doden *et al.* 2021; Ferguson *et al.* 2023; and references therein). Among 516 studied skulls, we only observed four cases of possible congenital abnormalities (in age classes D and E) and one possible case of neoplasia. In two cases, we observed abnormal holes or the absence of bone growth in the nasal bones. These holes were in close proximity to each other, so a predator's canines were excluded as a cause. With little evidence of bone healing, trauma is also less likely as a cause for these abnormalities.

The case of a midfacial cleft palate was noted in a male giraffe (NAM-HOA-1, *G. g. angolensis*, adult, Namibia) known in life (Fig. 9) and reported by Ferguson *et al.* (2023). The skull was discovered in northwest Namibia, after the individual was preyed upon by lions in October 2024 at nine years of age (A. Ekandjo pers. comm. 2024). The skull of this giraffe confirmed the previously reported (Ferguson *et al.* 2023) congenital abnormality of a non-fusion of the nasal and frontal bones. However, due to predation damage

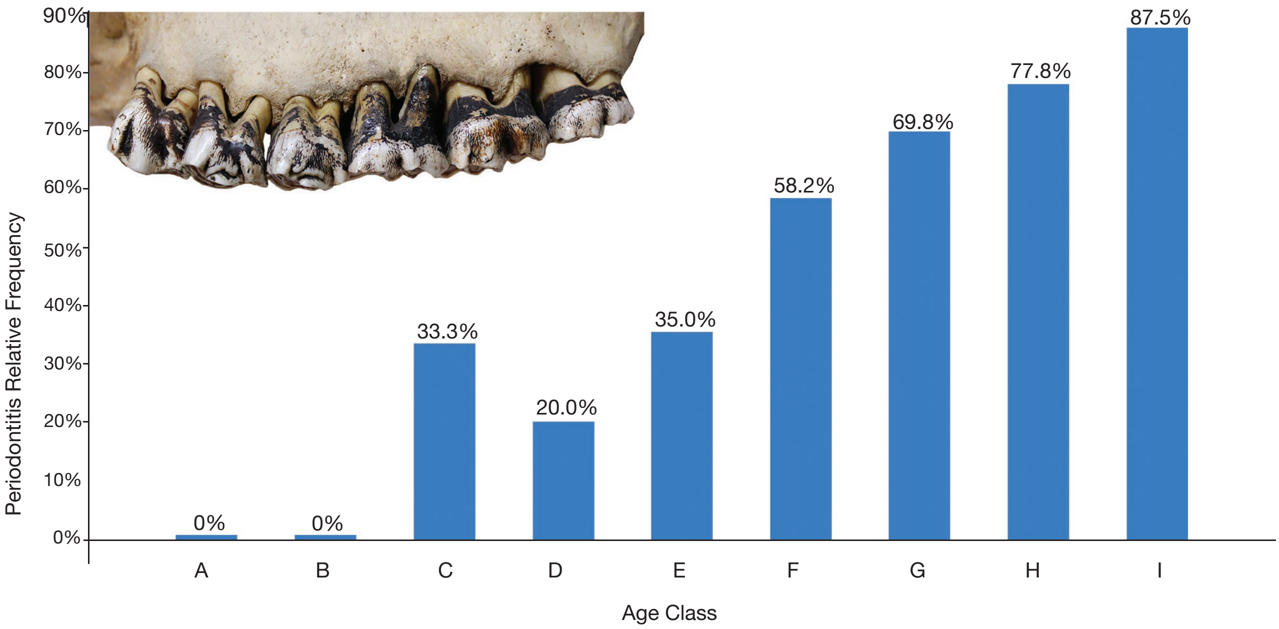

FIG. 10. — Relative frequencies of periodontitis in the studied age classes (**A**-**I**).

of the skull we could not determine whether the abnormality extended to the palatine bones of the hard palate. Since this giraffe was known while alive, we are aware that it was generally in good body condition and that it had no plant material around the nose during rumination or feeding (A. Ekandjo pers. comm. 2024) suggesting that a cleft of the hard or soft palate was unlikely.

Finally, our study reports one case of lateral deviation of the nasal bones consistent with wry nose, also previously described in wild giraffe (Ferguson *et al.* 2023). This was the first known case of wry nose in a male and Masai giraffe, with prior reports being restricted to females (Ferguson *et al.* 2023).

Interestingly, only one skull in our sample exhibited characteristics that suggested a neoplasm. The male had moderate to severe bone alterations of the right side of the skull extending from the mandible to the maxilla and including the base of the right ossicone and frontal portion of the skull. However, without histological evaluation of the bone, we cannot make a definite diagnosis, since aggressive osteomyelitis could also result in similar deviations of bone tissue.

Frequencies of the studied pathologies and irregularities

A considerable percentage of the studied sample exhibited pathologies or irregularities. In particular 284 specimens showed signs of irregularities/pathologies, corresponding to 55.0% of the total number of studied skulls. While 199 specimens only showed one deviation, 83 specimens (16.1%) showed multiple. Out of these 83 specimens, 70 (13.6%) presented two anomalies, 13 (2.5%) had three, and two specimens (0.4%) showed four different anomalies. The most common pathology was periodontitis (maxillary erosions) with a total of 206 specimens (39.9% of the sample), followed by the irregular morphology of the M3 (mainly concerning the size of the hypocone), which was detected in 72 specimens (14.0% of the sample). The rest of the anomalies were seen in percentages lower than 5%.

A more detailed distribution of the absolute and relative frequencies of the cases per species, subspecies, North/South, sex, and age can be seen in Table 1, whereas pairwise statistical significance between different groups can be found in Appendix 3. In terms of taxonomic distribution of all the cases, *G. camelopardalis* included 62 specimens with pathologies/irregularities (53.9%), *G. giraffa* showed 116 (64.4%), *G. reticulata* included 23 (67.7%; the highest in the sample), *G. tippelskirchi* showed 57 (44.2%; the lowest in the sample).

Dental irregularities (absent teeth, misaligned teeth, broken teeth, irregular dental morphology, and irregular dental wear) showed a relatively homogenous distribution in all groups. Taxonomically, they were mostly noted in *G. giraffa* (39.1%), and the lowest in *G. t. tippelskirchi* (12.4%). The relative frequency was higher in *G. c. camelopardalis* and *G. r. reticulata*, than in *G. giraffa* and *G. t. tippelskirchi*; but not statistically significant differences. The distribution were also similar between males and females. Juvenile specimens (age classes A and B) did not show any signs of such deviations, and most were observed in adults (33.3%) (Appendix 3).

Periodontitis was noted in 40 specimens for *G. camelopardalis* (34.8%; the lowest of the sample), 78 for *G. giraffa* (47.6%), 17 for *G. reticulata* (50%; the highest of the sample), and 50 for *G. tippelskirchi* (38.8%). Even though there are some differences in the percentages between the four species, no statistically significant separation was found. Similarly, no difference was found between males and females. However, there is a considerable difference in the presence of periodontitis in older individuals (Fig. 10). No maxillary erosions were found in the age classes A or B, followed by relatively low percentages in the age classes C, D, and E, whereas the relative frequencies become gradually higher in the older age classes, reaching 87.5% for age class I. Statistically significant differences were found between all the age groups and between most of the age classes.

Ossicone asymmetry, bending or breakage, was mostly found in *G. giraffa* (12.8%) and was significantly lower in *G. tippelskirchi* (5.4%). The other two species showed intermediate and not statistically significant positions. These deviations affected males (13.3%) more than females (3.1%), showing statistically significant differences, and supporting the hypothesis of fight-related trauma. The ossicone deviations are also only seen in adult and old individuals.

Finally, no statistically significant patterns were detected in the distribution of surface anomalies (nasal fistulae, expanded secondary ossification, cleft palate, neoplasia, periosteal reaction), even though most were male (n=14) versus female (n=2). As mentioned, this is not a random dataset, and the results can be biased by the ways of acquiring the specimens.

Conclusion

We reported a variety of cases of craniodental pathologies and irregularities. Our results suggest that more than half (55.0%) of the giraffe skulls had at least one pathology/irregularity and that 16.1% had more than one. Periodontitis was the most common with 39.9% of the sample, correlated with age, but not with taxonomy or sex. Dental irregularities are more common in *G. giraffa* and less in *G. tippelskirchi*, while they are absent in juveniles. The ossicones of males show more common fracture and bending, possibly due to fighting.

Acknowledgements

We are grateful to the curators and technicians of the visited institutions and the owners of the taxidermy companies that provided access to their collections and gave us inspiration through long discussions on our project (in alphabetical order of the institutes): L. Caspers (AMNH), E. Hoeger (AMNH), M. Surovy (AMNH), Dr S. Roussiakis (AMPG), C. Fraticelli – African Parks Network (CHA-ZAK), Dr A. Antonites (DNMNH), Dr H. Fourie (DNMNH), Dr A. Ferguson (FMNH), L. Johnson (FMNH), A. Feijó (FMNH), V. Simeonovski (FMNH), Dr G. Csorba (HNHM), Etosha Heights Private Reserve (NAM-ETO), S. Bean (NAM-ING), M. Egerer (NAM-NYA), Tau Taxidermy (NAM-TAU), P. Kamminga (NCB), P. Kokkini (NHMUK), Dr M. J. Fitzpatrick (NHMZ), Dr K. Gagisa Mkhwananzi (NHMZ), Dr S. Broadley (NHMZ), K. N. Langwane (NHMZ), T. Musareyana (NHMZ), Dr F. Zachos (NMW), A. Bibl (NMW), M. Rotonda (RMCA), E. Gilissen (RMCA), J. Opperman (SAM), P. Prins (SA-SI), Dr I. Ruf (SMF), K. Krohmann (SMF), Dr S. Merker (SMNS), C. Leidenroth (SMNS), Dr M. Sečanský (SNM), Dr V. Jansky (SNM), Uganda Wildlife Authority (UGA-MUR), D. Lunde (USNM), T. Hsu (USNM), F. Otten – Zambia Carnivore Program (ZAM-LUA), Dr E. Bärman (ZFMK), A. Pugh (ZIM-TCI), Prof. E. Valakos (ZMUA), Dr F. Mayer (ZMB), K. Mahlow (ZMB), M. Gärtner (ZMB), Dr A. van Heteren (ZSM). We would like to thank Dr L. Pandolfi and Dr L. Costeur for providing the 3D scans of the specimens housed in NMB, as well as P. Prins for providing the scans of the specimens from SA-SI. We would like to thank the Giraffe Conservation Foundation for their financial and technical support in making this study possible, and the Department of Biological Sciences at the University of Cape Town for hosting the project. Funding for this research was provided by the Giraffe Conservation Foundation. We would like to thank the two reviewers (Monica Bond and an anonymous reviewer) as well as the editors of *Zoosystema* for their suggestions and help concerning our manuscript.

REFERENCES

Al-Ani A. H., Antoun J. S., Thomson W. M., Merriman T. R. & Farella M. 2017. — Hypodontia: An Update on Its Etiology, Classification, and Clinical Management. *BioMed Research International* 2017: 9378325. https://doi.org/10.1155/2017/9378325

Albuquerque C., Morinha F., Requicha J., Martins T., Dias I., Guedes-Pinto H., Bastos E. & Viegas C. 2012. — Canine periodontitis: the dog as an important model for periodontal studies. *The Veterinary Journal* 191 (3): 299-305. https://doi.org/10.1016/j.tvjl.2011.08.017

Allen H., Barnthouse N. C. & Chan B. Y. 2022. — Periosteal Pathologic Conditions: Imaging Findings and Pathophysiology. *Radiograph* 43 (2): 1-17. https://doi.org/10.1148/rg.220120

Axenovich T. I., Zorkoltseva I. V., Aulchenko Y. S., Knyazev S. P. & Kulikova A. V. 2004. — Inheritance of Hypodontia in Kerry Blue Terrier Dogs. *Russian Journal of Genetics* 40: 529-536. https://doi.org/10.1023/B:RUGE.0000029156.13853.c0

Azorit C., Rodrigo M. J., Tellado S. & Sánchez-Ariza M. C. 2012. — Periodontal disease and fluoride bone levels in two separate Iberian red deer populations. *Animal Production Science* 52: 774-780. https://doi.org/10.1071/AN12014

Bertola L. D., Quinn L., Hanghøj K., Garcia-Erill G., Rasmussen M. S., Balboa R. F., Meisner J., Bøggild T., Wang X., Lin L., Nursyifa C., Liu X., Li Z., Chege M., Moodley Y., Brüniche-Olsen A., Kuja J., Schubert M., Agaba M., Santander C. G., Sinding M. -H., Muwanika V., Masembe C., Siegismund H., Moltke I., Albrechtsen A. & Heller R. 2024. — Giraffe lineages are shaped by major ancient admixture events. *Current Biology* 34: 1-11. https://doi.org/10.1016/j.cub.2024.02.051

Billet G., Hautier L., Asher R. J., Schwarz C., Crumpton N., Martin T. & Ruf I. 2012. — High morphological variation of vestibular system accompanies slow and infrequent locomotion in three-toed sloths. *Proceedings of the Royal Society B* 279: 3932-3939.

Boddaert P. 1784. — *Elenchus Animalium Vol. 1: Systems Quadrupedia*. C.R. Hake, Rotterdam, 174 p. https://doi.org/10.5962/bhl.title.40283

Bohner J., Bühler M., Bienert-Zeit A., Göritz F., Vogt C., Wohlsein P. & Azogu-Sepe I. 2021. — Complex Odontoma in a Young Captive Reticulated Giraffe (*Giraffa camelopardalis reticulata*). *Journal of Comparative Pathology* 185: 49-54. https://doi.org/10.1016/j.jcpa.2021.04.004

Borsanelli A. C., Lappin D. F., Viora L., Bennett D., Dutra I. S., Brandt B. W. & Riggio M. P. 2018. — Microbiomes associated with bovine periodontitis and oral health. *Veterinary Microbiology* 218: 1-6. https://doi.org/10.1016/j.vetmic.2018.03.016

Bowyer R. T., Stewart K. M., Kie J. G. & Gasaway W. C. 2001. — Fluctuating Asymmetry in Antlers of Alaskan Moose: Size Matters. *Journal of Mammalogy* 82 (3): 814-824. https://doi.org/10.1644/1545-1542(2001)082<0814:FAIAOA>2.0.CO;2

Brace C. L. 1964. — The probable mutation effect. *American Naturalist* 98 (903): 453-455. https://www.jstor.org/stable/41463056

Brand R. 2007. — *Evolutionary ecology of giraffes (*Giraffa camelopardalis*) in Etosha National Park, Namibia*. Unpublished PhD thesis, Newcastle University, Newcastle, 279 p.

Brown M. B. & Wells E. 2020. — Skeletal dysplasia-like syndromes in wild giraffe. *BMC Research Notes* 13: 569. https://doi.org/10.1186/s13104-020-05403-9

Brown M. B., Kulkarni T., Ferguson S., Fennessy S., Muneza A., Stabach J. A. & Fennessy J. 2021. — Conservation Status of Giraffe: Evaluating Contemporary Distribution and Abundance with Evolving Taxonomic Perspectives. *Imperilled: The Encyclopaedia of Conservation* 2022: 471-487. https://doi.org/10.1016/B978-0-12-821139-7.00139-2

Brünnich M. T. 1772. — *M. T. Brünnichii Zoologiae fundamenta, Grunde I Dyreloeren*. Apud Frider Christ Pelt, Hafniae et Lipsioe: 253 p. https://doi.org/10.5962/bhl.title.42672

Byles R. H. 1972. — Limiting conditions for the operation of the probable mutation effect. *Social Biology* 19 (1): 29-34. https://doi.org/10.1080/19485565.1972.9987962

Calcagno J. M. & Gibson K. 1988. — Human dental reduction: natural selection or the probable mutation effect. *American Journal of Physical Anthropology* 77: 505-517. https://doi.org/10.1002/ajpa.1330770411

Chirichella R., Rocca M., Brugnoli A., Mustoni A. & Apollonio M. 2020. — Fluctuating asymmetry in Alpine chamois horns: an indicator of environmental stress. *Evolutionary Ecology* 34: 573-587. https://doi.org/10.1007/s10682-020-10051-3

Clauss C., Franz-Odendaal T. A., Brasch J., Castell J. C. & Kaiser T. 2007. — Tooth wear in captive giraffes (*Giraffa camelopardalis*): mesowear analysis classifies free-ranging specimens as browsers but captive ones as grazers. *Journal of Zoo and Wildlife Medicine* 38 (3): 433-445. https://doi.org/10.1638/06-032.1

Coimbra R., Winter S., Kumar V., Koepfli K. -P., Gooley R., Dobrynin P., Fennessy J. & Janke A. 2021. — Whole-genome analysis of giraffe supports four distinct species. *Current Biology* 31: 2929-2938. https://doi.org/10.1016/j.cub.2021.04.033

Coimbra R., Winter S., Muneza A., Fennessy S., Otiende M., Mijele D., Masiaine S., Stacy-Dawes J., Fennessy J. & Janke A. 2023. — Genomic analysis reveals limited hybridisation among three giraffe species in Kenya. *BMC Biology* 21: 215. https://doi.org/10.1186/s12915-023-01722-y

Côté S. D. & Festa-Bianchet M. 2001. — Life-History Correlates of Horn Asymmetry in Mountain Goats. *Journal of Mammalogy* 82 (2): 389-400. https://doi.org/10.1644/1545-1542(2001)082<0389:LHCOHA>2.0.CO;2

Dagg A. I. 1971. — *Giraffa camelopardalis*. *Mammalian Species* 5: 1-8. https://doi.org/10.2307/3503830

Dagg A. I. 2014. — *Giraffe: Biology, Behaviour, and Conservation*. Cambridge University Press, Cambridge: 247 p. https://doi.org/10.1017/CBO9781139542302

Dixon P. M. & Vlaminck L. 2022. — Chapter 9: Abnormalities of craniofacial development and of dental development and eruption, *in* Easley J., Dixon P. & du Toit N. (eds), *Equine Dentistry and Maxillofacial Surgery*. Cambridge Scholars Publishing, Cambridge: 141-160.

Doden G., Garner M. M., Mangus L. M. & Sander S. 2021. — A retrospective survey of neoplasia in managed giraffes (*Giraffa camelopardalis*). *Journal of Zoo and Wildlife Medicine* 52 (1): 332-336. https://doi.org/10.1638/2020-0100

van Dyk E., Bosman A. M., van Wilpe E., Williams J. H., Bengis R. G., van Heerden J. & Venter E. H. 2011. — Detection and characterization of papillomavirus in skin lesions of giraffe and sable antelope in South Africa. *Journal of the South African Veterinary Association* 82 (2): 80-85. https://doi.org/10.4102/jsava.v82i2.39

Evenhuis J., Arzi B. & Verstraete F. J. M. 2022. — Systematic Assessment of Mammalian Skull Specimens for Dental and Temporomandibular Joint Pathology. *Journal of Visualized Experiments* 186: e64223. https://doi.org/10.3791/64223

Fennessy J., Bidon T., Reuss F., Kumar V., Elkan P., Nilsson M., Vamberger M., Fritz U. & Janke A. 2016. — Multi-locus Analyses Reveal Four Giraffe Species Instead of One. *Current Biology* 26: 2543-2549. https://doi.org/10.1016/j.cub.2016.07.036.

Ferguson S., Kaitho T., Lekolool I., Muneza A., Michelmore J., McFeeters L., Wells E., Ahl K., Hoffman R., Brown M., Fennessy S. & Fennessy J. 2023. — Congenital and Neoplastic Cranial Deformities in Wild Giraffe (*Giraffa* spp.). *Journal of Wildlife Disease* 59 (3): 472-478. https://doi.org/10.7589/JWD-D-22-00102

Flueck W. T. & Smith-Flueck J. M. 2022. — Cranial bone lesions in Patagonian huemul deer (*Hippocamelus bisulcus*): First description of a neonatal case. *Case Reports and Reviews: Open Access* 3 (2): 135.

Fortelius M. 1985. — Ungulate cheek teeth: developmental, functional, and evolutionary interrelations. *Acta Zoologica Fennica* 180: 1-76.

Franz-Odendaal T., Chinsamy A. & Lee-Thorp J. 2004. — High prevalence of enamel hypoplasia in an early Pliocene giraffid (*Sivatherium hendeyi*) from South Africa. *Journal of Vertebrate Paleontology* 24 (1): 235-244. https://www.jstor.org/stable/4524708

Franz-Odendaal T. A. & Kaiser T. M. 2003. — Differential mesowear in the maxillary and mandibular cheek dentition of some ruminants (Artiodactyla). *Annales Zoologici Fennici* 40: 395-410.

Fu Y. X. & Arnold J. 1992. — A Table of Exact Sample Sizes for Use with Fisher's Exact Test for 2 × 2 Tables. Biometrics 48: 1103-1112. https://doi.org/10.2307/2532702

Giavitto A. E. & Meehan L. J. 2020. — Congenital hypodontia in three horses diagnosed by computed tomography. *Equine Veterinary Education* 33: e219-e223. https://doi.org/10.1111/eve.13270.

Gisburne T. J. & Feldhamer G. A. 2005. — Dental anomalies in the gray fox *Urocyon cinereoargenteus* and the red fox *Vulpes vulpes*. *Acta Theriologica* 50 (4): 515-520. https://doi.org/10.1007/BF03192644

Goheen J. R. & Palmer T. M. 2010. — Defensive plantants stabilize megaherbivore driven landscape change in African savanna. *Current Biology* 20: 1768-1772. https://doi.org/10.1016/j.cub.2010.08.015

Govender R., Avery G. & Chinsamy A. 2011. — Pathologies in the Early Pliocene phocid seals from Langebaanweg, South Africa. *South African Journal of Science* 107 (1/2): 1-6. https://doi.org/10.4102/sajs.v107i1/2.230

Graïc J.-M., Peruffo A., Ballarin C. & Cozzi B. 2017. — The Brain of the Giraffe (*Giraffa camelopardalis*): Surface Configuration, Encephalization Quotient, and Analysis of the Existing Literature. *The Anatomical Record* 300 (8): 1502-1511. https://doi.org/10.1002/ar.23593

Hall R. E. 1940. — Supernumerary and Missing Teeth in Wild Mammals of the Orders Insectivora and Carnivora, with Some Notes on Disease. *Journal of Dental Research* 19 (2): 103-143. https://doi.org/10.1177/00220345400190020101

Hall-Martin A. J. 1976. — Dentition and age determination of the giraffe *Giraffa camelopardalis*. *Journal of Zoology, London* 180: 263-289.

Hammer Ø., Harper D. & Ryan D. 2001. — PAST: paleontological statistics software package for education and data analysis. *Palaeontologica Electronica* 4 (1): 1-9.

Han S., Dadone L., Ferguson S., Bapodra-Villaverde P., Dennis P., Aruho R., Sadar M., Fennessy J., Driciru M., Muneza A., Brown M., Johnston M. & Lahmers K. 2022. — Giraffe skin disease: Clinicopathologic characterization of cutaneous filariasis in the critically endangered Nubian giraffe (*Giraffa camelopardalis camelopardalis*). *Veterinary Pathology* 59 (3): 467-475. https://doi.org/10.1177/03009858221082606

von Hardenberg A., Bassano B., Arranz M. P. Z. & Bogliani G. 2004. — Horn growth but not asymmetry heralds the onset of senescence in male Alpine ibex (*Capra ibex*). *Journal of Zoology* 263: 425-432. https://doi.org/10.1017/S0952836904005485
Hassanin A., Jullemier E., Chardonnet B., Robinson T. J. 2026. — Species delimitation based on phylogenetic analyses of males: A case study revealing the complex evolutionary history of giraffes. *Molecular Phylogenetics and Evolution* 218, 108571. https://doi.org/10.1016/j.ympev.2026.108571
Jardine W. 1835. — *The Natural History of the Ruminating Animals, containing Deer, Antilopes, Camels &c.* W. H. Lizars, Edinburgh, 229 p. https://doi.org/10.5962/bhl.title.131528
Jentzsch M., Kraft R., Lemkul A., Kapischke H. -J., Maternowski H. -W. & Wolf R. 2020. — Anomalies and pathological changes of skulls and dentition of wild small mammal species from Germany. *Journal of Vertebrate Biology* 69 (4): 20072. https://doi.org/10.25225/jvb.20072
Jurado O. M., Clauss M., Streich J. & Hatt J. -M. 2008. — Irregular tooth wear and longevity in captive wild ruminants: a pilot survey of necropsy reports. *Journal of Zoo and Wildlife Medicine* 39 (1): 69-75. https://doi.org/10.1638/06-064.1
Kargopoulos N., Kampouridis P., Hartung J. & Böhme M. 2023. — Hyaenid remains from the Late Miocene of Kutschwan (Shanxi Province, China). *Paläontologische Zeitschrift* 97: 653-666. https://doi.org/10.1007/s12542-023-00658-6
Kargopoulos N., Marugán-Lobón J., Chinsamy A., Agwanda B., Brown M., Fennessy S., Ferguson S., Hoffman R., Lala F., Muneza A., Mwebi O., Otiende M., Petzold A., Winter S., Moussa Zabeirou A. R. & Fennessy J. 2024a. — Heads up – Four *Giraffa* species have distinct cranial morphology. *PLoS ONE* 19 (12): e0315043. https://doi.org/10.1371/journal.pone.0315043
Kargopoulos N., Rabe C., Gilissen E., Coudyzer W. & Chinsamy A. 2024b. — Multiple cranial pathologies in spotted hyaenas, *Crocuta crocuta*. *Zoology* 166: 126201. https://doi.org/10.1016/j.zool.2024.126201
Khanyile M., Ndou S. P. & Chimonyo M. 2014. — Influence of *Acacia tortilis* leaf meal-based diets on growth performance of pigs. *Livestock Science* 167: 211-218. https://doi.org/10.1016/j.livsci.2014.04.016
Kheloufi A., Mansouri L. M., Mami A. & Djelilate M. 2019. — Physio-biochemical characterization of two acacia species (*A. karroo* Hayn and *A. saligna* Labill.) under saline conditions. *Reforesta* 7: 33-49.
Krumbiegel I. 1971. — *Die Giraffe (*Giraffa camelopardalis*)*. A. Ziemsen Verlag, Wittenberg, 160 p.
Legendre L. 2018. — Small Mammal Oral and Dental Diseases, *in* Lobprise H. B. & Dodd J. R. (eds), *Wiggs's Veterinary Dentistry: Principles and Practice*. John Wiley & Sons, Inc., Hoboken: 463-480. https://doi.org/10.1002/9781118816219.ch21
Leighton B. C. 1991. — Aetiology of malocclusion of the teeth. *Archives of Disease in Childhood* 66: 1011-1012.
Linnaeus C. 1758. — *Systema Naturae per Regna Tria Naturae. Editio decima reformata, Tomus I.* Regnum Animale. Laurentius Salvius, Stockholm, 824 p. https://doi.org/10.5962/bhl.title.559
Lucas P. W. 2004. — *Dental functional morphology: how teeth work*. Cambridge University Press, Cambridge, 355 p. https://doi.org/10.1017/CBO9780511735011
Lydekker R. 1903. — Local variation in the Giraffe. *Animal Life and the World of Nature* 2: 78-84.
Lydekker R. 1911. — Two undescribed giraffes. *Nature* 87: 484. https://doi.org/10.1038/087484c0
Martins D. J. 2010. — Not all ants are equal: obligate acacia ants provide different levels of protection against mega-herbivores. *African Journal of Ecology* 48: 1115-1122. https://doi.org/10.1111/j.1365-2028.2010.01226.x
Matschie P. 1898. — Einige anscheinend noch nicht beschriebene Säugetiere aus Afrika. *Sitzungsbericht Gesellschaft Naturforschender Freunde zu Berlin* 1898: 75-81.
Mennecart B. & Costeur L. 2016. — Shape variation and ontogeny of the ruminant bony labyrinth, an example in Tragulidae. *Journal of Anatomy* 229: 422-435. https://doi.org/10.1111/joa.12487
Mills J. R. E. 1963. — Occlusion and malocclusion of the teeth of primates. *Dental Anthropology Journal* 1963: 29-51. https://doi.org/10.1016/B978-0-08-009823-4.50007-0
Mokoboki H. K., Ndlovu L. R., Ng'ambi J. W., Malatje M. M. & Nikolova R. V. 2005. — Nutritive value of Acacia tree foliages growing in the Limpopo Province of South Africa. *South African Journal of Animal Science* 35 (4): 221-228. https://doi.org/10.4314/sajas.v35i4.3963
Morens D. M., Holmes E. C., Davis A. S. & Taubengerger J. K. 2011. — Global Rinderpest Eradication: Lessons Learned and Why Humans Should Celebrate Too. *The Journal of Infectious Diseases* 204 (4): 502-505. https://doi.org/10.1093/infdis/jir327
Muller Z. 2018. — Population structure of giraffes is affected by management in the Great Rift Valley, Kenya. *PLoS ONE* 13 (1): e0189678. https://doi.org/10.1371/journal.pone.0189678
Muneza A., Montgomery R., Fennessy J., Dickman A., Roloff G. & Macdonald D. 2016. — Regional variation of the manifestation, prevalence, and severity of giraffe skin disease: A review of an emerging disease in wild and captive giraffe populations. *Biological Conservation* 198: 145-156. https://doi.org/10.1016/j.biocon.2016.04.014
Muneza A., Brown M. B., Fennessy S., Ferguson S., Hoffman R., Kargopoulos N., Kipchumba A., Koepfli K. -P., Marneweck C., Petzold A., Stabach J., Winter S. & Fennessy J. 2025. — Effective conservation and management of giraffe require adopting recent advances of their taxonomy. *Biodiversity and Conservation* 34: 1211-1229. https://doi.org/10.1007/s10531-025-03021-0
Natsume A., Koyasu K., Oda S., Nakagaki H., Kawai T. & Hanamura H. 2008. — Tooth size variability and relevance of numerical variation in the Japanese serow. Arch. *Oral Biology* 53 (1): 95-98. https://doi.org/10.1016/j.archoralbio.2007.07.013
Neville B. W., Damm D. D., Allen C. M. & Bouquot J. E. 2002. — *Oral and Maxillofacial Pathology*. W. B. Saunders Company, Philadelphia, 984 p.
Nieminen P. 2009. — Genetic basis of tooth agenesis. *Journal of Experimental Zoology Part B: Molecular and Developmental Evolution* 312B: 320-342.
O'Connor D., Stacy-Dawes J., Muneza A., Fennessy J., Gobush K., Chase M., Brown M., Bracis C., Elkan P., Moussa Zabeirou A. R., Rabeil R., Rubenstein D., Becker M., Phillips S., Stabach J., Leimgruber P., Glikman J., Ruppert K., Masiaine S. & Mueller T. 2019. — Updated geographic range maps for giraffe, *Giraffa* spp., throughout sub-Saharan Africa, and implications of changing distributions for conservation. *Mammal Review* 49: 285-299. https://doi.org/10.1111/mam.12165
Palmer A. R. 1994. — Fluctuating asymetry analyses: a primer, *in* Markow T. W. (ed.), *Developmental instability: its origins and evolutionary implications*. Kluwer Academic, New York: 333-364.
Pertoldi C., Jensen L. F., Olsen Alstrup A. K., Munk O. L., Pedersen T. B., Sonne C., Dietz R., Daugaard-Petersen T., Kortegaard H. E., Olsen M. T., Hårding K. C. & Jensen T. H. 2018. — Prevalence of skull parthologies in European harbor seals (*Phoca vitulina*) during 1981-2014. *Mammal Research* 63: 55-63. https://doi.org/10.1007/s13364-017-0340-2
Petzold A. & Hassanin A. 2020. — A comparative approach for species delimitation based on multiple methods of multi-locus DNA sequence analysis: A case study of the genus *Giraffa* (Mammalia, Cetartiodactyla). *PLoS ONE* 15 (2): e0217956. https://doi.org/10.1371/journal.pone.0217956
Pratt D. M. & Anderson V. H. 1982. — Population, distribution, and behaviour of giraffe in the Arusha National Park, Tanzania. *Journal of Natural History* 16: 481-489. https://doi.org/10.1080/00222938200770381
Pratt D. M. & Anderson V. H. 1985. — Giraffe social behaviour. *Journal of Natural History* 19: 771-781.

Satokata I. & Maas R. 1994. — *Msx1* deficient mice exhibit cleft palate and abnormalities of craniofacial and tooth development. *Nature Genetics* 6: 348-356.

Shorrocks B. 2016. — *The Giraffe: Biology, ecology, evolution and behaviour*. John Wiley & Sons, Chichester, 223 p. https://doi.org/10.1002/9781118587430

Simmons R. E. & Scheepers L. 1996. — Winning by a neck: sexual selection in the evolution of giraffe. *American Naturalist* 148 (5): 771-786. https://doi.org/10.1086/285955

Tague R. 2002. — Variability of metapodials in primates with rudimentary digits: *Ateles geoffroyi*, *Colobus guereza*, and *Perodicticus potto*. *American Journal of Physical Anthropology* 117: 195-208. https://doi.org/10.1002/ajpa.10028

Thomas O. 1898. — On a new subspecies of giraffe from Nigeria. *Proceedings of the Zoological Society of London* 1898: 39-41.

Van Valkenburgh B. 1988. — Incidence of tooth breakage among large, predatory mammals. *American Naturalist* 131 (2): 291-302. https://doi.org/10.1086/284790

Van Valkenburgh B. & White P. 2021. — Naturally-occurring tooth wear, tooth fracture, and cranial injuries in large carnivores from Zambia. *PeerJ* 9: e11313. https://doi.org/10.7717/peerj.11313

Verstraete F. J. M. 2003. — Advances in Diagnosis and Treatment of Small Exotic Mammal Dental Disease. *Seminars in Avian and Exotic Pet Medicine* 12 (1): 37-48. https://doi.org/10.1053/saep.2003.127877

Verstraete F. J. M., van Aarde R. J., Nieuwoudt B. A., Mauer E. & Kass P. H. 1996. — The Dental Pathology of Feral Cats on Marion Island, Part I: Congenital, Developmental and Traumatic Abnormalities. *Journal of Comparative Pathology* 115: 265-282. https://doi.org/10.1016/s0021-9975(96)80084-3

Wallis C. & Holcombe L. J. 2020. — A review of the frequency and impact of periodontal disease in dogs. *Journal of Small Animal Practice* 61 (9): 529-540. https://doi.org/10.1111/jsap.13218

Wilkens H. 1988. — Evolution and genetics of epigean and cave *Astyanax fasciatus* (Characidae, Pisces): Support for the neutral mutation theory. *Evolutionary Biology* 23: 271-367. https://doi.org/10.1007/978-1-4613-1043-3_8

Winter S., Fennessy J. & Janke A. 2018. — Limited introgression supports division of giraffe into four species. *Ecology and Evolution* 8: 10156-10165. https://doi.org/10.1002/ece3.4490

Winton W. D. de 1899. — On the giraffe of Somaliland (*Giraffa camelopardalis reticulata*). *Annales of the Magazine of Natural History* 7 (4): 211-212. https://doi.org/10.1080/00222939908678186

Submitted on 27 August 2025;
accepted on 27 January 2026;
published on 25 August 2026.

APPENDICES

Appendix 1. — Detailed catalogue of the studied specimens including the pathologies observed in them. Institutes (Inst.): **M**, museum; **T**, taxidermy company; **N**, natural park. Taxonomy: **N**, North; **S**, South; **X**, Unknown; **Gca**, *Giraffa camelopardalis antiquorum* Jardine, 1835; **Gcc**, *Giraffa camelopardalis camelopardalis* (Linnaeus, 1758); **Gcp**, *Giraffa camelopardalis peralta* Thomas, 1898; **Gcx**, *Giraffa camelopardalis* subsp.; **Gga**, *Giraffa giraffa angolensis* Lydekker, 1903; **Ggg**, *Giraffa giraffa giraffa* (Boddaert, 1784); **Ggx**, *Giraffa giraffa* subsp.; **Grr**, *Giraffa reticulata reticulata* de Winton, 1899; **Gtth**, *Giraffa tippelskirchi thornicrofti* Lydekker, 1911; **Gtti**, *Giraffa tippelskirchi tippelskirchi* Matschie, 1898; **Gxx**, *Giraffa* sp. subsp. Countries: **ANG**, Angola; **BOT**, Botswana; **CAM**, Cameroon; **CHA**, Chad; **DRC**, Democratic Republic of Congo; **ETH**, Ethiopia; **KEN**, Kenya; **NAM**, Namibia; **NGR**, Niger; **NIG**, Nigeria; **MOZ**, Mozambique; **SOM**, Somalia; **SSU**, South Sudan; **SUD**, Sudan; **TAN**, Tanzania; **UGA**, Uganda; **SAF**, South Africa; **ZIM**, Zimbabwe; **ZAM**, Zambia.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
AMNH/M/53544	M	N/Gca	F	A	DRC, Faradje	–
SMF/4509	M	N/Gca	F	B	CAM, Djimtilo	–
AMNH/M/53549	M	N/Gca	F	D	DRC, Garamba	M1 (109 and 209) mesostyle not connected to the metacone
NHMUK/ZD/1902/11/12/1	M	N/Gca	F	D	SSU, Kodok	–
SMF/4465	M	N/Gca	F	D	CAM, Djimtilo	Very short M3 (111) hypocone
AMNH/M/53543	M	N/Gca	F	E	DRC, Faradje	Periodontitis on P2 (106) – mild
NHMUK/ZD/1907/7/8/255	M	N/Gca	F	E	CHA, Chari River	–
NHMW/4832/B/4980	M	N/Gca	F	E	CAM, Wolodje	Periodontitis on M3(111 and 211) - moderate 211; mild 111
RMCA/RG/3748	M	N/Gca	F	E	DRC, Kapili	Dentine connection between the lingual and buccal cusps of P3 (107 and 207). Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
RMCA/RG/3749	M	N/Gca	F	E	DRC, Kapili	Double crista in M1 (209)
RMCA/RG/21645	M	N/Gca	F	E	CHA, Aouk	Very short M3 (111 and 211) hypocone
SMF/497	M	N/Gca	F	E	SUD, S Darfur	Very short M3 (111 and 211) hypocone
SMF/4466	M	N/Gca	F	E	CAM, Djimtilo	Periodontitis on M3 (211) - mild
AMNH/M/53546	M	N/Gca	F	F	DRC, Garamba	Periodontitis on M1 (209) - moderate
RMCA/RG/3710	M	N/Gca	F	F	DRC, Garamba NP	Very short M3 (111 and 211) hypocone
NMB/12075	M	N/Gca	F	G	DRC, Garamba	–
RMCA/RG/25548	M	N/Gca	F	I	DRC, Gangala na Bodio	Extended periodontitis - severe wear in all teeth; exposed pulp cavities 107, 109, 110, 209-211
AMNH/M/53548	M	N/Gca	M	B	DRC, Garamba	–
NHMUK/ZD/1906/2/12/1	M	N/Gca	M	B	NIG, Yola	–
NHMUK/ZD/1928/11/11/24	M	N/Gca	M	B	CHA, Bidadi	–
AMNH/M/53550	M	N/Gca	M	E	DRC, Garamba	–
CHA/ZAK/2	N	N/Gca	M	E	CHA, Zakouma	–
CHA/ZAK/3	N	N/Gca	M	E	CHA, Zakouma	–
NHMUK/ZD/1906/2/12/2	M	N/Gca	M	E	NIG, Yola	Right ossicone bent caudally - No obvious signs of trauma - likely congenital
RMCA/RG/83.006/M/0553	M	N/Gca	M	E	DRC, Garamba	Misaligned P4 (108 and 208). Extended periodontitis - moderate left side
RMCA/RG/3747	M	N/Gca	M	E	DRC, Kapili	Very short M3 (111 and 211) hypocone
RMCA/RG/25673	M	N/Gca	M	E	DRC, Gangala na Bodio	Misaligned P4 (208). Nasal fistulae
CHA/ZAK/4	N	N/Gca	M	F	CHA, Zakouma	–
NHMUK/ZD/1938/7/8/22	M	N/Gca	M	F	CAM, Bi-Inda	Periodontitis on molars (109-111 and 209-211) moderate to mild in 209-211; mild in 109-111. Possible trauma on the left auditory and occipital region
NHMW/B/5342	M	N/Gca	M	F	CHA, Melfi	Extended periodontitis - mild to moderate
RMCA/RG/3709	M	N/Gca	M	G	DRC, Garamba NP	–
RMCA/RG/25672	M	N/Gca	M	H	DRC, Gangala na Bodio	Extended periodontitis - moderate to severe left side; mild right side
CHA/ZAK/1	N	N/Gca	M	E+	CHA, Zakouma	–
CHA/ZAK/5	N	N/Gca	M	E+	CHA, Zakouma	–
NHMUK/ZD/1910/5/16/2	M	N/Gca	M	E+	CHA, Chari River	–
RMCA/RG/8648	M	N/Gca	M	E+	DRC, Faradje	–
SMF/498	M	N/Gca	M	C-E	SUD, S Darfur	–
ZMB/48222	M	N/Gca	M	E+	CAM	–
FMNH/127887	M	N/Gcc	F	A	KEN, Cherangany Hills	–
FMNH/127886	M	N/Gcc	F	D	KEN, Cherangany Hills	Irregular lingual crista on P4 (108 and 208)
NHMUK/ZD/1873/8/29/7	M	N/Gcc	F	E	ETH, Dembelas	Buccal aspects of all premolars angled towards the lingual surface
NMK/OM9278	M	N/Gcc	F	D	KEN, Kitale	–
ZMB/MAM/17502	M	N/Gcc	F	E	ETH, Galla	Periodontitis on P4 (108) - moderate
NHMUK/ZD/1901/8/9/49	M	N/Gcc	F	F	KEN, Uasin-Gishu	Periodontitis on M1 (109 and 209) - moderate
NHMUK/ZD/1901/8/9/50	M	N/Gcc	F	F	KEN, Uasin-Gishu	Periodontitis on M1 (109) - mild
UGA/MUR/2	N	N/Gcc	F	F	UGA, Murchison Falls	Periodontitis on M1 (109) and M3 (211) - moderate
SMNS/Z/MAM/30171	M	N/Gcc	F	G	SSU, Jonglei, Boma	Extended periodontitis - mild
NHMUK/ZD/1903/4/16/1	M	N/Gcc	F	H	KEN, Lake Baringo	Periodontitis on M1 (109 and 209) - moderate
FMNH/127885	M	N/Gcc	F	I	KEN, Cherangany Hills	Extended periodontitis - severe

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
UGA/MUR/11	N	N/Gcc	F	E+	UGA, Murchison Falls	–
UGA/MUR/4	N	N/Gcc	F	E+	UGA, Murchison Falls	–
FMNH/127884	M	N/Gcc	M	A	KEN, Cherangany Hills	–
SMF/78004	M	N/Gcc	M	A	UGA	–
USNM/163112	M	N/Gcc	M	A	KEN, Lime Spring	–
USNM/299998	M	N/Gcc	M	A	Zoo Washington DC	–
FMNH/27475	M	N/Gcc	M	D	UGA, Northern	Very short M3 (111 and 211) hypocone
NMK/OM9279	M	N/Gcc	M	E	KEN, Kitale	Periodontitis on P4 (108 and 208) - mild
UGA/MUR/3	N	N/Gcc	M	E	UGA, Murchison Falls	–
UGA/MUR/8	N	N/Gcc	M	E	UGA, Murchison Falls	Periodontitis on M1 (209) - moderate
USNM/163113	M	N/Gcc	M	E	KEN, Guaso Nyiro River	Very short M3 (111 and 211) hypocone
USNM/163312	M	N/Gcc	M	E	KEN, Uasin-Gishu	–
USNM/200151	M	N/Gcc	M	E	KEN, Uasin-Gishu	P4 (208) fractured. Extended periodontitis - moderate to severe
FMNH/127882	M	N/Gcc	M	F	KEN, Cherangany Hills	–
FMNH/127883	M	N/Gcc	M	F	KEN, Cherangany Hills	–
NHMUK/ZD/1902/11/13/2	M	N/Gcc	M	F	SSU, Juba, Mongalla	Absent P2 (106)
NMK/Amboseli3	M	N/Gcc	M	F	KEN, Ruma NP	Periodontitis on M1 (209) - mild
NMK/Amboseli6	M	N/Gcc	M	F	KEN, Ruma NP	Extended periodontitis - mild to moderate. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NMK/OM2094	M	N/Gcc	M	F	KEN, Soy	Very short M3 (111 and 211) hypocone. Extended periodontitis - mild
NMK/OM2275	M	N/Gcc	M	F	KEN, Trans-Nzoia, Kitale	Extended periodontitis - mild
UGA/MUR/5	N	N/Gcc	M	F	UGA, Murchison Falls	–
UGA/MUR/6	N	N/Gcc	M	F	UGA, Murchison Falls	–
UGA/MUR/7	N	N/Gcc	M	F	UGA, Murchison Falls	Periodontitis on P4 (208) - mild
USNM/121010	M	N/Gcc	M	F	KEN, Uasin-Gishu	Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
USNM/155438	M	N/Gcc	M	F	KEN, Lake Baringo	M3 (111 and 211) hypocone almost absent. Distinct secondary ossification centres mesially to the orbits - possible periosteal reaction to fighting
ZSM/1911/2443	M	N/Gcc	M	F	KEN, Lake Baringo	Periodontitis on M1 (109) – mild. Right ossicone bent caudally - No obvious signs of trauma - likely congenital
NHMUK/ZD/1901/8/9/47	M	N/Gcc	M	G	KEN, Uasin-Gishu	Extended periodontitis - mild
NMK/OM2097	M	N/Gcc	M	G	KEN, Uasin Gishu, Soy	Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZFMK/MAM/2002/0027	M	N/Gcc	M	G	SSU, Bahr El Zeraf	Periodontitis on M1 (209) – mild. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
UGA/MUR/15	N	N/Gcc	M	H	UGA, Murchison Falls	–
NHMUK/ZD/1964/225	M	N/Gcc	M	I	UGA, Karamoja	Extended periodontitis - severe wear all teeth; exposed pulp cavities in 110-111
NMK/OM2099	M	N/Gcc	M	I	KEN, Soy	Extended periodontitis - moderate to severe
NMK/Amboseli1	M	N/Gcc	M	X	KEN, Ruma NP	–
NMK/Amboseli2	M	N/Gcc	M	X	KEN, Ruma NP	–
NMK/Amboseli4	M	N/Gcc	M	X	KEN, Ruma NP	–
NMK/Amboseli5	M	N/Gcc	M	X	KEN, Ruma NP	–
UGA/MUR/1	N	N/Gcc	M	E+	UGA, Murchison Falls	–
UGA/MUR/10	N	N/Gcc	M	E+	UGA, Murchison Falls	Extended periodontitis - mild to moderate
UGA/MUR/12	N	N/Gcc	M	E+	UGA, Murchison Falls	–
UGA/MUR/13	N	N/Gcc	M	E+	UGA, Murchison Falls	Shallow pit between the left ossicone and the left orbit that is surrounded by developed secondary ossification (more than on the right side), possibly a fight injury
UGA/MUR/14	N	N/Gcc	M	E+	UGA, Murchison Falls	–
UGA/MUR/9	N	N/Gcc	M	E+	UGA, Murchison Falls	Extended periodontitis - mild to moderate
USNM/304612	N	N/Gcc	M	E+	Zoo Washington DC	Extended periodontitis - mild to moderate
NER/KOU/1	N	N/Gcp	F	E	NGR, Koure	Periodontitis on premolars - mild in 106-108
NER/KOU/3	N	N/Gcp	F	E	NGR, Kour	Left ossicone bent nearly 90 degrees from skull - Possible signs of trauma
NER/KOU/2	N	N/Gcp	F	H	NGR, Kour	Periodontitis on M1 (209) - moderate
NER/KOU/7	N	N/Gcp	F	I	NGR, Kour	Extended periodontitis - moderate to severe - especially 209/109
NHMUK/ZD/1898/2/18/1	M	N/Gcp	M	E	NIG, SE Benue & Niger	–
NER/KOU/8	N	N/Gcp	M	F	NGR, Kour	Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
NHMUK/ZD/1904/11/2/2	M	N/Gcp	M	F	NIG, E of Sharu	Both ossicones bent right - No obvious signs of trauma - likely congenital
NER/KOU/4	N	N/Gcp	M	E+	NGR, Kour	–
NER/KOU/5	N	N/Gcp	M	E+	NGR, Kour	–
NER/KOU/6	N	N/Gcp	X	A	NGR, Kour	–
NER/KOU/9	N	N/Gcp	X	C+	NGR, Kour	–
USNM/252549	M	N/Gcx	F	B	SUD	–
USNM/252585	M	N/Gcx	F	B	SUD	Boney alteration of zygomatic bone and the maxilla; separation of the sutures between the zygomatic and maxillary bones ventral to the left orbit – Possible disease process or trauma
NHMUK/ZD/1901/5/14/1	M	N/Gcx	F	D	SUD, Bahr-el-Gebel/W. Nile	–
NHMUK/ZD/1908/8/12/2	M	N/Gcx	F	D	NIG	–
NHMW/5574	M	N/Gcx	F	F	SUD	–
RMCA/RG/767	M	N/Gcx	M	E	SSU, Lado	Very short M3 (111) hypocone. Extended periodontitis - severe in 106-7 and 207-209. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter - left ossicone also noticeably thinner than right ossicone
ZMB/MAM/31781	M	N/Gcx	M	E	SSU, Bahr al Jabal	–
ZSM/1912/0705	M	N/Gcx	M	F	SUD, W. Nile	Extended periodontitis - mild to moderate. Both ossicones bent left - No obvious signs of trauma - likely congenital
ZSM/1912/729	M	N/Gcx	M	F	SSU, Upper Nile	Periodontitis on M1 (109) - moderate
NHMW/5575	M	N/Gcx	M	G	SUD	Absent P2 (106) - possibly lost and healed. Misaligned P2 (206). M1 (109) rotten - discoloured with severe carries
SMF/16148	M	N/Gcx	M	G	SSU, Bor	Extended periodontitis - moderate
NHMW/5552	M	N/Gcx	M	I	SUD	Periodontitis on M1 (209) - mild
AMNH/M/165052	M	S/Gga	F	B	NAM, Lombart Farm	–
NAM/ING/2923	T	S/Gga	F	B	NAM, Wilhelmstal Noord 8	–
NHMUK/ZD/1938/7/8/21	M	S/Gga	F	B	ANG, Bala Huti	–
NAM/ING/2874	T	S/Gga	F	C	NAM, Masindi 370	Periodontitis on M1 (209) - mild
NAM/ING/K77	T	S/Gga	F	C	NAM	–
NAM/NYA/4	N	S/Gga	F	C	NAM	–
NAM/ING/2164	T	S/Gga	F	D	NAM, Okamahoro 19	Misaligned P2 (106 and 206)
NAM/ING/2590	T	S/Gga	F	D	NAM, Erora W 13	Very short M3 (111 and 211) hypocone
NAM/ING/2645	T	S/Gga	F	D	NAM, Okamahoro 19	–
ZMB/MAM/33884	N	S/Gga	F	D	NAM	–
ZMB/MAM/58976	N	S/Gga	F	G	NAM, Okahandja	–
NAM/NYA/18	T	S/Gga	F	F?	NAM	Periodontitis on molars - mild to moderate
AMNH/M/165051	M	S/Gga	M	C	NAM, Lombart Farm	Very short M3 (111 and 211) hypocone. Periodontitis on P2 (106) - moderate
SAM/ZM/39527	M	S/Gga	M	C	NAM	–
NAM/HOA/1	N	S/Gga	M	E	NAM, Hoanib River	Very short M3 (111) hypocone. Cleft palate
NAM/ING/2852	T	S/Gga	M	E	NAM, Wilhelmstal	–
NAM/ING/2971	T	S/Gga	M	E	NAM, Otjikoko-S #61	Very short M3 (111 and 211) hypocone
NAM/NYA/10	T	S/Gga	M	E	NAM	Periodontitis on P2 (206) - mild
NAM/NYA/11	T	S/Gga	M	E	NAM	Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NAM/NYA/13	T	S/Gga	M	E	NAM	–
NAM/NYA/15	T	S/Gga	M	E	NAM	–
NAM/NYA/17	T	S/Gga	M	E	NAM	Very short M3 (211) hypocone
NAM/NYA/5	T	S/Gga	M	E	NAM	Periodontitis on M1 (109 and 209) - mild
NAM/NYA/6	T	S/Gga	M	E	NAM	Periodontitis on M2 (210) - mild
NAM/NYA/7	T	S/Gga	M	E	NAM	–
NAM/NYA/9	T	S/Gga	M	E	NAM	Periodontitis on P3 (207) and M2 (110)
NAM/TAU/1366	T	S/Gga	M	E	NAM	–
NAM/TAU/1606	T	S/Gga	M	E	NAM	Periodontitis on M1 (109) – severe. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter. Right ossicone bent laterally - No obvious signs of trauma - likely congenital
NAM/TAU/1700	T	S/Gga	M	E	NAM	Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
SAM/ZM/39692	M	S/Gga	M	E	NAM, Witvlei	Very short M3 (111 and 211) hypocone
DNMNH/TM/12141	M	S/Gga	M	F	NAM, Kaokoveld	Very short M3 (211) hypocone
NAM/ETH/1	N	S/Gga	M	F	NAM, Etosha Heights PR	Very short M3 (111) hypocone. Extended periodontitis - mild

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
NAM/ING/2288	T	S/Gga	M	F	NAM, Woltemade	Misaligned M3 (111). Periodontitis on P2 (106 and 206) - moderate
NAM/ING/2787	T	S/Gga	M	F	NAM, Okamahoro 19	Right ossicone shorter - Possible signs of trauma - right distal ossicone slanted - possible complete fracture of distal ossicone
NAM/NYA/14	T	S/Gga	M	F	NAM	Periodontitis on M1 (109) - mild
NAM/NYA/3	T	S/Gga	M	F	NAM	Possible healed fractures in 209-210 - on buccal aspect. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NAM/TAU/32	T	S/Gga	M	F	NAM	Very short M3 (111 and 211) hypocone. M2 (110 and 210) - in 210 severe discoloration/rotted; in 110 moderate discoloration and more worn on lingual aspect
ZMB/MAM/66393	M	S/Gga	M	F	NAM, Okahandja	–
NAM/NYA/1	T	S/Gga	M	G	NAM	Extended periodontitis - mild
NAM/NYA/16	T	S/Gga	M	G	NAM	Periodontitis on premolars – mild. Right ossicone shorter - Possible signs of trauma - right distal ossicone slanted - possible complete fracture of distal ossicone
NAM/NYA/2	T	S/Gga	M	G	NAM	Extended periodontitis - moderate
NAM/ETH/2	N	S/Gga	M	E+	NAM, Etosha Heights PR	Extended periodontitis – moderate. Right ossicone shorter – Possible signs of trauma - right ossicone shortened and wider/stubbier than left ossicone - possibly similar to other male that has fractured distal ossicone that healed
NAM/NYA/12	T	S/Gga	M	E+	NAM	Extended periodontitis - mild to moderate
NAM/NYA/8	T	S/Gga	M	G+	NAM	Extended periodontitis - mild to moderate
NHMZ/29121	M	S/Ggg	F	A	ZIM, Doddieburn R.	–
NHMZ/29114	M	S/Ggg	F	B	BOT, Mohembo	–
NHMZ/60806	M	S/Ggg	F	B	BOT, Chobe GR	–
NHMZ/60812	M	S/Ggg	F	B	ZIM, Lake Chivero	–
DNMNH/AZ/635	M	S/Ggg	F	C	SAF, Langjan NR	Periodontitis on premolars - mild in 108 and 206-8
DNMNH/TM/12255	M	S/Ggg	F	C	SAF, Klaserie	Very short M3 (111 and 211) hypocone
DNMNH/TM/12256	M	S/Ggg	F	C	SAF, Klaserie	M3 (111 and 211) hypocone almost absent. Periodontitis on premolars - moderate in 106-108 and mild to moderate in 206-208
NHMUK/ZD/1972/1323	M	S/Ggg	F	C	SAF, Maadji Mountains	–
NHMZ/60809	M	S/Ggg	F	C	ZIM, Doddieburn R.	Periodontitis on premolars - mild
NHMZ/60813	M	S/Ggg	F	C	ZIM, Matopos NP	Extended periodontitis - moderate
DNMNH/AZ/2336	M	S/Ggg	F	D	SAF, Kruger NP	Extended periodontitis - mild
FMNH/34423	M	S/Ggg	F	D	BOT, Mabebe Flats	Periodontitis on premolars - mild
FMNH/34427	M	S/Ggg	F	D	BOT, Mabebe Flats	–
NHMZ/60805	M	S/Ggg	F	D	BOT, Chobe GR	–
UCT/BCO/1	M	S/Ggg	F	D	SAF	–
DNMNH/TM/3314	M	S/Ggg	F	E	ZIM, Jabwiela	Very short M3 (111 and 211) hypocone
NHMZ/60804	M	S/Ggg	F	E	BOT, Chobe GR	Very short M3 (111 and 211) hypocone
NMB/12076	M	S/Ggg	F	E	SAF, Mkuze	Very short M3 (111 and 211) hypocone
DNMNH/CR/684	M	S/Ggg	F	F	SAF, Lydenburg	–
FMNH/34424	M	S/Ggg	F	F	BOT, Mabebe Flats	Misaligned P3 (207). Very short M3 (111 and 211) hypocone. Periodontitis on P2 (106) and M3 (111 and 211) - mild
NHMZ/26184	M	S/Ggg	F	F	ZIM, Doddieburn R.	M3 (111 and 211) hypocone almost absent. Periodontitis on premolars - mild
NHMZ/60803	M	S/Ggg	F	F	BOT, Chobe GR	M3 (111 and 211) hypocone almost absent. Periodontitis on premolars - mild
ZIM/TCI/002	T	S/Ggg	F	F	ZIM, Cawston	Extended periodontitis - mild
ZIM/TCI/005	T	S/Ggg	F	F	ZIM	Periodontitis on M1 (109 and 209) - mild
NHMZ/60810	M	S/Ggg	F	G	ZIM, Kyle	Periodontitis on premolars - moderate to mild
SA/SI/8	T	S/Ggg	F	E-F	SAF, E Cape	–
AMPG/EV/318	M	S/Ggg	M	A	BOT, Chitabe	–
DNMNH/TM/13397	M	S/Ggg	M	A	SAF, Klaserie	–
FMNH/34428	M	S/Ggg	M	A	BOT, Mabebe Flats	–
AMNH/M/83605	M	S/Ggg	M	B	ZIM, Ngamo Station	–
DNMNH/TM/12254	M	S/Ggg	M	B	SAF, Klaserie	–
NHMUK/ZD/1966/429	M	S/Ggg	M	B	ZIM, Doddieburn R.	–
NHMZ/60807	M	S/Ggg	M	B	BOT, Chobe GR	–
NHMZ/60811	M	S/Ggg	M	B	MOZ, Setache	–
SAM/ZM/37058	M	S/Ggg	M	C	SAF, Phalaborwa	–
FMNH/33429	M	S/Ggg	M	D	BOT, Mabebe Flats	Very short M3 (111 and 211) hypocone
SA/SI/10	T	S/Ggg	M	D	SAF, E Cape	–
USNM/154033	M	S/Ggg	M	D	ZIM, Matabeleland	–
ZIM/TCI/X2	T	S/Ggg	M	D	ZIM	Very short M3 (111) hypocone

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
ZIM/TCI/X5	T	S/Ggg	M	D	ZIM	Extended periodontitis - moderate to severe
FMNH/236496	M	S/Ggg	M	E	SAF, Bateleur Saf. Camp	–
NHMZ/23979	M	S/Ggg	M	E	ZIM, Towla	–
NHMZ/23983	M	S/Ggg	M	E	ZIM, Towla	Very short M3 (111 and 211) hypocone. Periodontitis on P2 (106 and 206) - mild
NHMZ/26180	M	S/Ggg	M	E	ZIM, Doddieburn R.	–
NHMZ/26186	M	S/Ggg	M	E	ZIM, Doddieburn R.	Very short M3 (111 and 211) hypocone. Periodontitis on premolars - mild in 206-207; moderate in 106-107
NHMZ/26187	M	S/Ggg	M	E	ZIM, Doddieburn R.	–
NHMZ/26188	M	S/Ggg	M	E	ZIM, Doddieburn R.	Extended periodontitis - mild to moderate
NHMZ/26189	M	S/Ggg	M	E	ZIM, Doddieburn R.	Very short M3 (111 and 211) hypocone. Periodontitis on M1 (209) - mild
NHMZ/29100	M	S/Ggg	M	E	ZIM, Doddieburn R.	Periodontitis on premolars - mild
NHMZ/29101	M	S/Ggg	M	E	ZIM, Matopos NP	M3 (111 and 211) hypocone almost absent. Periodontitis on premolars - mild
NHMZ/29102	M	S/Ggg	M	E	ZIM, Doddieburn R.	Very short M3 (111 and 211) hypocone
NHMZ/60802	M	S/Ggg	M	E	BOT, Ngamiland, Chobe GR	Periodontitis on M1 (109) - severe
SA/SI/1	T	S/Ggg	M	E	SAF, E Cape	–
SA/SI/2	T	S/Ggg	M	E	SAF, E Cape	–
SA/SI/3	T	S/Ggg	M	E	SAF, E Cape	–
SA/SI/4	T	S/Ggg	M	E	SAF, E Cape	–
SA/SI/6	T	S/Ggg	M	E	SAF, E Cape	–
ZIM/TCI/036	T	S/Ggg	M	E	ZIM	Very short M3 (111 and 211) hypocone. Possible healed fracture in M3 (211). Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/076	T	S/Ggg	M	E	ZIM, Cawston	–
ZIM/TCI/089	T	S/Ggg	M	E	ZIM	Very short M3 (111 and 211) hypocone. Compression fracture of right ossicone causing shortening - Possible signs of trauma
ZIM/TCI/181a	T	S/Ggg	M	E	ZIM, Chishakwe	Only P2 (206) severely worn
ZIM/TCI/188	T	S/Ggg	M	F	ZIM	Periodontitis on M2 (110 and 210) - mild to moderate in 110; mild in 210
ZIM/TCI/206	T	S/Ggg	M	E	ZIM, Sango	Periodontitis on M1 (209) - mild
ZIM/TCI/219a	T	S/Ggg	M	E	ZIM, Cawston	–
ZIM/TCI/219b	T	S/Ggg	M	E	ZIM	Very short M3 (111 and 211) hypocone. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/249	T	S/Ggg	M	E	ZIM	Very short M3 (211) hypocone. Periodontitis on M2 (210)-mild buccally and moderate lingually
ZIM/TCI/253	T	S/Ggg	M	E	ZIM, Cawston	M3 (111 and 211) hypocone almost absent. Periodontitis on M1 (209) - mild
ZIM/TCI/319	T	S/Ggg	M	E	ZIM, Msaise	M3 (111 and 211) hypocone almost absent
ZIM/TCI/371a	T	S/Ggg	M	E	ZIM, Cawston	Very short M3 (111 and 211) hypocone
ZIM/TCI/405	T	S/Ggg	M	E	ZIM, Matetsi	Extended periodontitis - mild
ZIM/TCI/453	T	S/Ggg	M	E	ZIM, Humani	Very short M3 (111 and 211) hypocone. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/462	T	S/Ggg	M	E	ZIM, Bishopstone	Very short M3 (111 and 211) hypocone. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/472	T	S/Ggg	M	E	ZIM, Mazunga	Only P4 (208) severely worn, maybe a retained DP4. Periodontitis on P4 (208) – moderate. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/490a	T	S/Ggg	M	E	ZIM, Bedford	–
ZIM/TCI/X7	T	S/Ggg	M	E	ZIM	Periodontitis on molars - moderate
ZMB/MAM/15552	M	S/Ggg	M	E	SAF, W Cape	Periodontitis on M1 (209) - mild to moderate
ZSM/2010/551	M	S/Ggg	M	E	SAF	Very strange M3 (111 and 211) shape. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NHMUK/ZD/1842/12/6/16	M	S/Ggg	M	F	SAF	Extended periodontitis - mild to moderate
NHMUK/ZD/1931/2/1/48	M	S/Ggg	M	F	BOT, Mogogilo River	M3 (211) hypocone almost absent
NHMZ/23978	M	S/Ggg	M	F	ZIM, Towla	Very short M3 (111 and 211) hypocone. Periodontitis on premolars - mild
NHMZ/23984	M	S/Ggg	M	F	ZIM, Towla	Periodontitis on P2 (106 and 206) - mild

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
NHMZ/26178	M	S/Ggg	M	F	ZIM, Doddieburn R.	Possible healed fractures in the M3 (211) and the lingual aspect of 109 and 110. Periodontitis on premolars – moderate. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NHMZ/26179	M	S/Ggg	M	F	ZIM, Doddieburn R.	Periodontitis on molars - mild in 109; mild to moderate in 209-211
NHMZ/26185	M	S/Ggg	M	F	ZIM, Doddieburn R.	Extended periodontitis - moderate
NHMZ/26200	M	S/Ggg	M	F	ZIM, Doddieburn R.	Extended periodontitis - mild
NHMZ/27144	M	S/Ggg	M	F	ZIM, Gulweni Area	Periodontitis on M1 (109 and 209) - mild-moderate in 209; mild in 109
NHMZ/29111	M	S/Ggg	M	F	BOT, Chobe GR	Extended periodontitis - mild
SA/SI/11	T	S/Ggg	M	F	SAF, E Cape	–
SA/SI/5	T	S/Ggg	M	F	SAF, E Cape	–
SA/SI/9	T	S/Ggg	M	F	SAF, E Cape	–
SAM/ZM/36655	M	S/Ggg	M	F	SAF, W Cape Tygerberg Zoo	Irregular cristae in P2 (206). Misaligned P3 (207)
ZIM/TCI/015	T	S/Ggg	M	F	ZIM, Woodlands	Extended periodontitis - mild to moderate, worse on the left side. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/103	T	S/Ggg	M	F	ZIM, Matetsi	Very short M3 (111 and 211) hypocone. Extended periodontitis - mild
ZIM/TCI/181b	T	S/Ggg	M	F	ZIM	Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/255	T	S/Ggg	M	F	ZIM	Extended periodontitis - mild
ZIM/TCI/302	T	S/Ggg	M	F	ZIM, Hwange	Extended periodontitis – mild. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/364	T	S/Ggg	M	F	ZIM	Very short M3 (111 and 211) hypocone. Periodontitis on premolars - mild in 106-107 and 206-208. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
ZIM/TCI/404	T	S/Ggg	M	F	ZIM, Humani	Extended periodontitis - mild to moderate
ZIM/TCI/490b	T	S/Ggg	M	F	ZIM, Humani	Very short M3 (111 and 211) hypocone. Extended periodontitis - mild
ZIM/TCI/X3	T	S/Ggg	M	F	ZIM, W Nicholson	Irregular M1 (109) hypocone/protocone
FMNH/34422	M	S/Ggg	M	G	BOT, Mabebe Flats	Fractures on the buccal sides of left toothrow. Extended periodontitis – moderate. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter. Both ossicones bent right - No obvious signs of trauma - likely congenital
FMNH/34425	M	S/Ggg	M	G	BOT, Mabebe Flats	Worn P3 (207) lingual surface. Very strange M3 (111 and 211) shape. Periodontitis on molars - mild
NHMUK/ZD/1972/1322	M	S/Ggg	M	G	SAF	Fractures on the buccal sides of the molars. Extended periodontitis - moderate
NHMZ/29112	M	S/Ggg	M	G	BOT, Chobe GR	Extended periodontitis - moderate to severe, worse on left side. Severe periosteal reaction/secondary ossification between ossicones - no obvious involvement of median ossicone
NHMZ/29113	M	S/Ggg	M	G	BOT, Chobe GR	Extended periodontitis - mild
ZIM/TCI/X1	T	S/Ggg	M	G	ZIM	Extended periodontitis - moderate
NHMZ/60801	M	S/Ggg	M	H	BOT, Chobe GR	Only M1 (209) worn. Extended periodontitis – mild. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
SA/SI/7	T	S/Ggg	M	H	SAF, E Cape	–
ZIM/TCI/401	T	S/Ggg	M	I	ZIM, Cawston	Extended periodontitis - severe wear in 207 and 209; moderate in the remaining ones
NHMZ/58342	N	S/Ggg	M	F+	ZIM, E of Fishons	Extended periodontitis – severe. Periosteal reaction mesially to the left orbit
NHMZ/60800	N	S/Ggg	M	G+	ZIM, Nuanetsi	Extended periodontitis - severe; pulp cavities exposed in 108 and 110
USNM/296145	N	S/Ggg	M	H+	NAM, Gaucha	Extended periodontitis - severe
ZIM/TCI/291	T	S/Ggg	M	F+	ZIM	Misaligned M3 (111). Very short M3 (111 and 211) hypocone
ZIM/TCI/371b	T	S/Ggg	M	G+	ZIM, Mazunga	Extended periodontitis - mild to moderate. Moderate periosteal reaction/secondary ossification of skull dorsal to the right orbit - possible depression fracture that has healed

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
ZIM/TCI/X4	T	S/Ggg	M	E+	ZIM	Both ossicones bent right - No obvious signs of trauma – likely congenital/developed shorter. Possible healed depression fracture of right frontal bone dorsally to the orbit
ZIM/TCI/X6	T	S/Ggg	M	E+	ZIM	Extended periodontitis - moderate to severe
SAM/ZM/39204	M	S/Ggg	X	A	SAF, Paarl	–
SAM/ZM/39558	M	S/Ggg	X	A	SAF, Villiersdorp	–
SAM/ZM/39795	M	S/Ggg	X	A	SAF, Paarl	–
NHMZ/26177	M	S/Ggg	X	B	ZIM, Doddieburn R.	–
NHMZ/60808	M	S/Ggg	X	B	ZIM, Doddieburn R.	–
AMNH/M/83459	M	S/Ggx	F	A	BOT, Mababe Flats	–
AMNH/M/83458	M	S/Ggx	F	D	BOT, Mababe Flats	Very short M3 (111 and 211) hypocone
NHMUK/ZD/1939/4329a	M	S/Ggx	F	E	BOT, Ngamiland	M3 (111 and 211) hypocone almost absent. Periodontitis on M1 (209) and M2 (210) - moderate, possible tooth root abscess 210, may involve 209
ZFMK/MAM/1984/0003	M	S/Ggx	F	G	SAF Zoo Köln	Periodontitis on molars - moderate in 109-111 and 209-211
ZMB/MAM/23432	M	S/Ggx	F	E+	NAM, Caprivi	–
ZMB/MAM/86240	M	S/Ggx	F	E+	NAM, Caprivi	–
AMNH/M/24290	M	S/Ggx	M	E	BOT, Tuley	Very short M3 (111 and 211) hypocone. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
AMNH/M/24291	M	S/Ggx	M	E	BOT, Tuley	Very short M3 (111 and 211) hypocone
AMNH/M/24292	M	S/Ggx	M	E	BOT, Tuley	–
AMNH/M/24293	M	S/Ggx	M	F	BOT, Tuley	Very short M3 (111 and 211) hypocone. Extended periodontitis - mild
AMNH/M/83460	M	S/Ggx	M	F	BOT, Mababe Flats	M3 (111 and 211) hypocone almost absent
NHMUK/ZD/1906/10/26/1	M	S/Ggx	M	F	ANG	Misaligned P2 (206)
NHMUK/ZD/1923/1/17/8	M	S/Ggx	M	F	ANG, Upper Lobito	–
NHMW/4127	M	S/Ggx	M	F	BOT, Ngamiland	Extended periodontitis - moderate to severe
ZFMK/MAM/80.320	M	S/Ggx	M	F	SAF, Zoo Köln	–
AMNH/M/82002	M	N/Grr	F	D	KEN, N Ewaso Nyiro	–
ZSM/1960/0078	M	N/Grr	F	D	KEN, N Zoo Hellabrunn	–
NHMUK/ZD/1912/2/24/1	M	N/Grr	F	E	KEN, Archer‘s Post	Very short M3 (111 and 211) hypocone
NMK/OM2279	M	N/Grr	F	D	KEN, Meru	Periodontitis on P2 (106 and 206) - mild
ZFMK/MAM/1990/0004	M	N/Grr	F	E	Zoo Köln	–
FMNH/32901	M	N/Grr	F	F	ETH, Burgi	Additional lingual cusp on P2 (106) and on P3 (106). Irregular lingual cusp on P4 (108 and 208). Periodontitis on M1 (209) - moderate
FMNH/32902	M	N/Grr	F	F	ETH, Burgi	Very short M3 (111 and 211) hypocone. Periodontitis on molars - mild
NHMUK/ZD/1912/2/24/2	M	N/Grr	F	F	KEN, Archer‘s Post	Premolars - mild in 106-107
NMK/OM2272	M	N/Grr	F	F	KEN, Nanyuki	Misaligned P4 (108)
NHMW/26429/ST/292	M	N/Grr	F	G	SOM, Djilandu	Extended periodontitis - moderate
USNM/163324	M	N/Grr	F	G	KEN, Ewaso Nyiro	Misaligned P2 (106). M1 (209) rotten and decayed/worn on the lingual aspect; discolored. Extended periodontitis - mild to moderate
ZSM/1967/0017	M	N/Grr	F	G	KEN, N Zoo Hellabrunn	Extended periodontitis - mild to moderate
FMNH/32904	M	N/Grr	M	A	ETH, Burgi	–
ZSM/1956/0017	M	N/Grr	M	B	KEN, N Zoo Hellabrunn	–
FMNH/32905	M	N/Grr	M	D	ETH, Burgi	–
AMNH/M/82001	M	N/Grr	M	E	KEN, N Ewaso Nyiro	Periodontitis on M2 (110) - moderate
NHMUK/ZD/1899/7/8/5	M	N/Grr	M	E	KEN, E Loroghi Mountains	–
NHMUK/ZD/1923/10/20/8	M	N/Grr	M	E	SOM, Jubaland	Right ossicone shorter - Possible signs of trauma - compression fracture of right ossicone causing shortening
NMK/Bwatherong	M	N/Grr	M	E	KEN, Meru	M1 (209) fractured
NMK/OM2215	M	N/Grr	M	E	KEN, Meru	Extended periodontitis - moderate
NMK/OM2281	M	N/Grr	M	E	KEN, Meru	–
NMK/OM5458	M	N/Grr	M	E	KEN, NE	Extended periodontitis - moderate
NHMUK/ZD/1897/1/30/1	M	N/Grr	M	F	KEN, E Loroghi Mountains	M3 (111 and 211) hypocone almost absent. Periodontitis on M1 (109 and 209) - moderate in 209; mild to moderate in 109
NMK/Elsa25	M	N/Grr	M	F	KEN, Meru	Periodontitis on P2 (106) and P3 (207) - moderate

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
NMK/No Nu	M	N/Grr	M	F	KEN, Meru	P4 (108) fractured. Right ossicone shorter - Possible signs of trauma - compression fracture of right ossicone causing shortening
USNM/182192	M	N/Grr	M	F	KEN, Ewaso Ngiro	Periodontitis on molars - moderate in 109-111; moderate to severe in 210-211
USNM/304613	M	N/Grr	M	F	Zoo Washington DC	Only distal part of M1 (209) worn
ZMB/MAM/84955	M	N/Grr	M	F	KEN, Ewaso Nyiro	–
USNM/182125	M	N/Grr	M	G	KEN, Marsabit Road	Extended periodontitis - severe
NMK/Mururi57	M	N/Grr	M	H	KEN, Meru	Fractured buccal sides of right toothrow. Extended periodontitis - moderate
SMF/501	M	N/Grr	M	H	SOM, Wante	Extended periodontitis - moderate to severe
USNM/182124	M	N/Grr	M	H	KEN, Marsabit Road	Extended periodontitis - severe
AMNH/M/82003	M	N/Grr	X	A	KEN, N Ewaso Nyiro	–
NHMUK/ZD/1923/10/20/19	M	N/Grr	X	A	SOM, Jubaland	–
ZAM/LUA/04	N	S/Gtth	F	F	ZAM, Luangwa Valley	Extended periodontitis - moderate
ZAM/LUA/10	N	S/Gtth	F	G	ZAM, Luangwa Valley	–
NHMZ/11533	M	S/Gtth	F	E-F	ZAM, Luangwa Valley	Very short M3 (111 and 211) hypocone. Extended periodontitis - moderate
NHMZ/11644	M	S/Gtth	M	B	ZAM, Luangwa Valley	–
NHMZ/22959	M	S/Gtth	M	B	ZAM, Luangwa Valley	–
NHMUK/ZD/1907/2/4/15	M	S/Gtth	M	D	ZAM, Luangwa Valley	–
NHMZ/20382	M	S/Gtth	M	E	ZAM, Luangwa Valley	Moderate diastema between 206 and 207. Periodontitis on P2 (206)
NHMZ/11525	M	S/Gtth	M	E+	ZAM, Luangwa Valley	Extended periodontitis - moderate
NHMZ/20221	M	S/Gtth	M	E+	ZAM, Luangwa Valley	Extended periodontitis - mild to moderate
NHMZ/22635	M	S/Gtth	M	E+	ZAM, Luangwa Valley	Extended periodontitis – severe. Right ossicone bent caudally and laterally. Neoplastic changes - enlarged boney growth at base of right ossicone - corresponding ramus of mandible abnormal.
NHMZ/22862	M	S/Gtth	M	E+	ZAM, Luangwa Valley	Periodontitis on M1 (209) - moderate
NHMZ/29099	M	S/Gtth	M	E+	ZAM, Luangwa Valley	Extended periodontitis - mild to moderate
ZAM/LUA/01	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
ZAM/LUA/02	N	S/Gtth	M	E+	ZAM, Luangwa Valley	Periodontitis on M1 (109) - moderate
ZAM/LUA/03	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
ZAM/LUA/05	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
ZAM/LUA/06	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
ZAM/LUA/07	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
ZAM/LUA/08	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
ZAM/LUA/09	N	S/Gtth	M	E+	ZAM, Luangwa Valley	–
NHMZ/22957	M	S/Gtth	X	A	ZAM, Luangwa Valley	–
FMNH/29515	M	S/Gtti	F	B	KEN, Athi River	–
NMB/9153	M	S/Gtti	F	B	TAN, Tanganyika	–
USNM/162989	M	S/Gtti	F	B	KEN, Guaso Nyiro	–
ZMB/MAM/41538	M	S/Gtti	F	B	TAN, Mount Meru	–
AMNH/M/27753	M	S/Gtti	F	C	KEN, Komarock	–
RMCA/RG/6341	M	S/Gtti	F	C	TAN, Ufipa	–
SMF/23030	M	S/Gtti	F	C	TAN	–
ZMB/MAM/84942	M	S/Gtti	F	C	KEN, Maasai Mara	–
NMK/OM7544	M	S/Gtti	F	D	KEN, Magadi Road	Periodontitis on P4 (108) - mild
RMCA/RG/6342	M	S/Gtti	F	D	TAN, Ufipa	–
SMNS/Z/MAM/16925	M	S/Gtti	F	D	TAN	–
ZMB/MAM/32373	M	S/Gtti	F	D	KEN, Coast, Oldorobo	–
ZSM/1914/0559	M	S/Gtti	F	D	TAN, Serengeti	Periodontitis on M2 (110) - mild
NHMW/5549	M	S/Gtti	F	E	KEN, Maasai Mara	Compression fracture with partially healed bone at cranial base of right ossicone - Signs of trauma
NMK/ESK3	M	S/Gtti	F	E	KEN, Eselenkay	Periodontitis on P4 (108) and M1 (109) - mild
NMK/KM	M	S/Gtti	F	E	KEN, Kimana	Misaligned premolars (106-108 and 206-208)
ZMB/MAM/42103	M	S/Gtti	F	E	KEN, Kiboko River	–
FMNH/127880	M	S/Gtti	F	F	TAN, Seronera	Periodontitis on M1 (109 and 209) and M2 (110 and 210) - mild
NMK/ESK4	M	S/Gtti	F	F	KEN, Eselenkay	Periodontitis on P2 (106) and P3 (107) - mild
NMK/OM2278	M	S/Gtti	F	F	KEN, Athi River	Misaligned P2 (206). Extended periodontitis - moderate
SMNS/Z/MAM/19138	M	S/Gtti	F	F	KEN, Maasai Mara	Periodontitis on premolars - moderate in 106 and 207, mild in 206 and 208
USNM/162988	M	S/Gtti	F	F	KEN, Guaso Nyiro	M3 (111 and 211) hypocone almost absent. Extended periodontitis - moderate, worse on right side
USNM/251798	M	S/Gtti	F	F	TAN, Dodoma	–
USNM/251800	M	S/Gtti	F	F	TAN	Very short M3 (111 and 211) hypocone
ZMB/MAM/84948	M	S/Gtti	F	F	TAN, Kilimanjaro	–

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
ZMB/MAM/84954	M	S/Gtti	F	F	TAN, Uzungwe Mountains	Extended periodontitis - mild
ZMB/MAM/84960	M	S/Gtti	F	F	TAN, Arusha	Periodontitis on P3 (207) and M1 (209) - mild
ZSM/1911/2446	M	S/Gtti	F	F	TAN, Serengeti	M1 (209) worn more on distal aspect. P4 (108) lost. Extended periodontitis - severe
NHMW/7535	M	S/Gtti	F	G	TAN, Prov. Arusha	Extended periodontitis - mild
NHMW/974	M	S/Gtti	F	G	KEN, Serengeti	Misaligned P2 (106) and P3 (107). P4 (108) lost. Extended periodontitis – severe. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NMK/G6	M	S/Gtti	F	G	KEN, Tsavo E NP	–
NMK/G10	M	S/Gtti	F	G	KEN, Tsavo E NP	–
SMF/500	M	S/Gtti	F	G	TAN	Periodontitis on M2 (110 and 210) and M3 (111 and 211) - moderate
USNM/251797	M	S/Gtti	F	G	TAN, Dodoma	Very short M3 (111 and 211) hypocone. Extended periodontitis - mild to moderate
ZMB/MAM/84961	M	S/Gtti	F	G	TAN, Mkamba	–
NHMUK/ZD/1900/3/18/3	M	S/Gtti	F	H	KEN, Athi Plains	Periodontitis on molars - severe in 109-110
NMK/G5	M	S/Gtti	F	H	KEN, Tsavo E NP	–
SMF/15919	M	S/Gtti	F	H	TAN, Zoo Frankfurt	Periodontitis on molars - severe in 109-111 and 210-211
NMK/OM6103	M	S/Gtti	F	X	KEN, Ngong Hills	Extended periodontitis - moderate
ZMB/MAM/10889	M	S/Gtti	F	E+	KEN, Taveta	–
ZMB/MAM/84951	M	S/Gtti	F	C-	TAN, Lake Eyasi	–
ZMB/MAM/84952	M	S/Gtti	F	E+	TAN, Nguru Mountains	–
ZMB/MAM/84966	M	S/Gtti	F	C-	TAN, Tabora	–
FMNH/127879	M	S/Gtti	M	A	TAN, Seronera	–
NMK/OM2090	M	S/Gtti	M	A	KEN, Kedong	–
NMK/OM7717	M	S/Gtti	M	A	KEN, Athi River	–
AMNH/M/54122	M	S/Gtti	M	B	KEN, Kajiado	–
NHMUK/ZD/1899/12/10/1	M	S/Gtti	M	B	KEN, Rhombo River	–
NHMUK/ZD/1899/12/10/2	M	S/Gtti	M	B	KEN, Rhombo River	–
NMK/OM2089	M	S/Gtti	M	B	KEN, Nairobi NP	–
ZMB/MAM/84958	M	S/Gtti	M	B	TAN, Nguru Mountains	–
USNM/162017	M	S/Gtti	M	D	KEN, Kapiti Plateau	–
FMNH/127881	M	S/Gtti	M	E	TAN, Seteti	–
NHMUK/ZD/1933/4/2/2	M	S/Gtti	M	E	TAN, Tanganyika	Very short M3 (111 and 211) hypocone
NMB/8664	M	S/Gtti	M	E	TAN, Arusha	–
NMK/G1	M	S/Gtti	M	E	KEN, Tsavo E NP	–
NMK/OM2096	M	S/Gtti	M	E	KEN, Ruiru	Misaligned M3 (111). Periodontitis on molars - mild in 109, moderate in 111
NMK/OM2217	M	S/Gtti	M	E	KEN, Sinac Ranch	–
NMK/OM6507	M	S/Gtti	M	E	KEN, Magadi	Periodontitis on M1 (109 and 209) - mild
USNM/162016	M	S/Gtti	M	E	KEN, Kapiti Plateau	Periodontitis on M1 (109 and 209) - mild
USNM/251799	M	S/Gtti	M	E	TAN, Mkata Plains	–
ZMB/MAM/32372	M	S/Gtti	M	E	KEN, Oldorobo	–
ZSM/1911/2444	M	S/Gtti	M	E	TAN	–
ZSM/1913/1056	M	S/Gtti	M	E	TAN, Kilimanjaro	–
ZSM/1914/0127	M	S/Gtti	M	E	TAN, Kilimanjaro	Wry Nose
ZSM/1914/1326	M	S/Gtti	M	E	TAN, Mwanza	–
AMNH/M/27752	M	S/Gtti	M	F	KEN, Maungu	Periodontitis on M1 (109 and 209) - mild
FMNH/34930	M	S/Gtti	M	F	KEN, Sagalla	Periodontitis on M2 (210) - mild
HNHM/60.208.1	M	S/Gtti	M	F	TAN, Tanganyika	Periodontitis on P2 (106 and 206) - moderate
NMK/ESK1	M	S/Gtti	M	F	KEN, Eselenkay	–
NMK/Mgeno1	M	S/Gtti	M	F	KEN, Mgeno Conservancy	–
NMK/OM2214	M	S/Gtti	M	F	KEN, Kitengela	Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NMK/OM2299	M	S/Gtti	M	F	KEN, Ngong Hills	Extended periodontitis - moderate to severe
RMCA/RG/2128	M	S/Gtti	M	F	KEN, Maasai Mara	Extended periodontitis - moderate to severe
SMF/35595	M	S/Gtti	M	F	TAN	–
USNM/162018	M	S/Gtti	M	F	KEN, Ulu Station	Irregular cusps - P4 (108). Periodontitis on M1 (109 and 209) - mild
ZMB/MAM/17381	M	S/Gtti	M	F	TAN, Nguru Mountains	Severe periosteal reaction/secondary ossification of frontal bone on the left aspect of the skull; possible fracture and trephination into frontal sinus, obvious hole into what should be the frontal sinus - healed
ZSM/1907/0861	M	S/Gtti	M	F	TAN, Kilimanjaro	Very short M3 (111 and 211) hypocone

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
FMNH/127878	M	S/Gtti	M	G	TAN, Seronera	Very short M3 (111 and 211) hypocone. Extended periodontitis - moderate to mild, worse on left side. Left ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter. Periosteal reaction on the right maxilla distally to the M3 (111)
NMK/ANP1	M	S/Gtti	M	G	KEN, Amboseli NP	Extended periodontitis - moderate
NMK/G9	M	S/Gtti	M	G	KEN, Tsavo E NP	Extended periodontitis - moderate to severe
NMK/X1	M	S/Gtti	M	G	KEN, Tsavo W NP	Extended periodontitis - mild
SMNS/Z/MAM/16928	M	S/Gtti	M	G	TAN	Extended periodontitis - moderate
ZMB/MAM/84957	M	S/Gtti	M	G	TAN, Kondoa	–
ZSM/1911/2445	M	S/Gtti	M	G	TAN, Arusha	Periodontitis on premolars - moderate in 106-108 and 206-208
NHMUK/ZD/1898/7/2/5	M	S/Gtti	M	H	KEN, W of Mombasa	Irregular cristae in P2 (206). Only M1 (109) abnormally worn, more so on the proximal lingual aspect. Extended periodontitis - moderate
NHMUK/ZD/1962/220	M	S/Gtti	M	H	KEN, Langata	Extended periodontitis - mild-moderate, worse on right side at 109-110. Right ossicone shorter - No obvious signs of trauma - likely congenital/developed shorter
NMK/G8	M	S/Gtti	M	H	KEN, Tsavo E NP	–
RMCA/RG/6343	M	S/Gtti	M	H	TAN, Ufipa	Extended periodontitis - moderate
ZFMK/MAM/38.36	M	S/Gtti	M	H	TAN, Arusha	Extended periodontitis - severe; left side more prevalent. Right ossicone thickened, shorter than left ossicone and bent backwards - Possible signs of trauma
NMK/G3	M	S/Gtti	M	I	KEN, Tsavo E NP	–
ZSM/1914/1325	M	S/Gtti	M	I	TAN, Mwanza	Extended periodontitis – severe. Severe periosteal reaction/seconary ossification at multiple points across the skull; possible hole/trephination in frontal bone lateral to the medial ossicone on the left. Also abnormal hole on the right maxilla; periosteal changes to the right maxilla and zygomatic bone possibly from periosteal disease
NHMW/27317	M	S/Gtti	M	E+	TAN, Masailand	–
NMK/ANP2	M	S/Gtti	M	X	KEN, Amboseli NP	–
NMK/ESK2	M	S/Gtti	M	X	KEN, Eselenkay	–
NMK/G2	M	S/Gtti	M	X	KEN, Tsavo E NP	Extended periodontitis - severe
NMK/MasaiMara1	M	S/Gtti	M	X	KEN, Maasai Mara	–
NMK/MasaiMara2	M	S/Gtti	M	X	KEN, Maasai Mara	–
NMK/Mgeno2	M	S/Gtti	M	X	KEN, Mgeno Conservancy	Extended periodontitis - moderate to severe
NMK/Mgeno3	M	S/Gtti	M	X	KEN, Mgeno Conservancy	–
NMK/OM7064	M	S/Gtti	M	X	KEN, Lukenya	Extended periodontitis - moderate to severe
NHMUK/ZD/1909/11/27/1	M	S/Gtti	X	A	KEN, Sultan Hamud	–
ZMB/MAM/109868	M	S/Gtti	X	A	KEN, Dönje Erok	–
ZMB/MAM/84964	M	S/Gtti	X	A	TAN, Umba Steppe	–
ZMB/MAM/31393	M	S/Gtti	X	B	TAN, Grumeti River	–
ZMB/MAM/84959	M	S/Gtti	X	B	TAN, Uzungwe Mountains	–
NMK/OM2276	M	S/Gtti	X	B	KEN, Kitengela	–
ZMB/MAM/109858	M	S/Gtti	X	B+	KEN, Dönje Erok	–
SMNS/Z/MAM/7592	M	X/Gxx	F	A	Zoo Karlsruhe	–
RMNH/MAM/4107	M	X/Gxx	F	B	Zoo Blijdorp	–
SAM/ZM/36851	M	X/Gxx	F	B	Unknown	–
SAM/ZM/035364	M	X/Gxx	F	C	Unknown	–
DNMNH/AZ/121	M	X/Gxx	F	D	Zoo Pretoria	Extended periodontitis - mild
NHMUK/ZD/1898/7/2/6	M	X/Gxx	F	D	KEN, NE of Lake Baringo	–
NHMW/5483	M	X/Gxx	F	D	KEN	Periodontitis on M3 (111 and 211) – moderate. Nasal fistulae
RMNH/MAM/10873	M	X/Gxx	F	D	Zoo Blijdorp	–
NMK/OM2088	M	X/Gxx	F	E	Unknown	Misaligned P4 (108 and 208)
RMNH/MAM/51477	M	X/Gxx	F	F	Unknown	–
SMNS/Z/MAM/45425	M	X/Gxx	F	F	Zoo Wilhelma	Irregular M2 (110 and 210) lingual profile. Absent M3 (111 and 211). Distal 1/3 of right ossicone bent backwards with possible callus formation - Possible fracture that healed
ZSM/1901/0109	M	X/Gxx	F	F	Unknown	–
HNHM/64.76.1	M	X/Gxx	F	G	Unknown	–

Appendix 1. — Continuation.

Inventory	Inst.	Taxonomy	Sex	Age	Provenance	Pathology
RMCA/RG/7963	M	X/Gxx	F	G	Unknown	Very short M3 (111 and 211) hypocone. Periodontitis on molars - severe in 110-111 and 209-211
SMNS/Z/MAM/49722	M	X/Gxx	F	I	Zoo Wilhelma	Very strange M3 shape - abnormal lingual cusps in 111 and very irregular rounded shape in 211. Periodontitis on molars - severe in 109-111 and 210-211
SNM/C/1840	M	X/Gxx	F	I	Zoo Bratislava	Extended periodontitis - moderate to severe
ZSM/1914/0760	M	X/Gxx	F	I	Unknown	Extended periodontitis - moderate to severe
DNMNH/TM/12257	M	X/Gxx	F	E+	Zoo Pretoria	Extended periodontitis - mild
FMNH/15576	M	X/Gxx	F	C-E	ETH	Extended periodontitis - mild
RMNH/MAM/7085	M	X/Gxx	F	E+	Zoo Blijdorp	–
SMF/95435	M	X/Gxx	F	E+	Zoo Frankfurt	–
RMNH/MAM/51478	M	X/Gxx	M	A	Zoo Blijdorp	–
SAM/ZM/33540	M	X/Gxx	M	A	Unknown	–
ZSM/1967/189	M	X/Gxx	M	A	Zoo Hellabrunn	–
ZSM/1980/0255	M	X/Gxx	M	A	Zoo Hellabrunn	–
RMNH/MAM/10874	M	X/Gxx	M	B	Zoo Blijdorp	–
RMNH/MAM/11662	M	X/Gxx	M	B	Zoo Blijdorp	–
RMNH/MAM/4216a	M	X/Gxx	M	B	Zoo Blijdorp	–
SAM/ZM/035365	M	X/Gxx	M	B	Unknown	–
SMNS/Z/MAM/51688	M	X/Gxx	M	B	Unknown	–
SMNS/Z/MAM/6857	M	X/Gxx	M	B	Zoo Wilhelma	–
ZSM/AM/0638	M	X/Gxx	M	B	Unknown	–
HNHM/64.11.1	M	X/Gxx	M	D	Unknown	Periodontitis on M1 (109 and 209) - mild
HNHM/66.30.1	M	X/Gxx	M	D	Unknown	–
AMNH/M/54123	M	X/Gxx	M	E	KEN	Extended periodontitis - moderate to severe
HNHM/64.262.1	M	X/Gxx	M	E	Unknown	Extended periodontitis - mild to moderate
HNHM/68.390.1	M	X/Gxx	M	E	Unknown	Extended periodontitis – mild. Left ossicone thickened, distal 1/4 portion bent backwards - Possible healed fracture
NMK/OM2092	M	X/Gxx	M	E	Unknown	Periodontitis on P3 (107) – moderate. Right ossicone shorter - No obvious signs of trauma - likely congenital/ developed shorter
SAM/ZM/17176	M	X/Gxx	M	E	ZAM	–
SMNS/Z/MAM/16927	M	X/Gxx	M	E	Unknown	–
NMB/C.1917	M	X/Gxx	M	F	Unknown	–
RMCA/RG/5956	M	X/Gxx	M	F	DRC	Periodontitis on molars - mild to moderate in 209-210; mild in 109-110
SAM/ZM/36654	M	X/Gxx	M	F	Unknown	Extended periodontitis - moderate
NMK/OM2903	M	X/Gxx	M	G	Unknown	Exended periodontitis - mild to moderate
HNHM/83.65.1	M	X/Gxx	M	H	Unknown	Extended periodontitis - moderate to severe, worse on right side
NHMW/40884	M	X/Gxx	M	I	Zoo Vienna	Right ossicone shorter - No obvious signs of trauma - however unusual multiple bulbous ossifications in straight line up right ossicone
NMK/OM7006	M	X/Gxx	M	I	Unknown	Extended periodontitis - severe
NMK/OM9100	M	X/Gxx	M	I	Unknown	Extended periodontitis - severe, more prevalent on the left side
SMF/95896	M	X/Gxx	M	I	Zoo Frankfurt	Very short M3 (111 and 211) hypocone. Extended periodontitis - mild in left side; severe in 109-110
NMK/OM2095	M	X/Gxx	M	X	Unknown	–
NMK/OM4956	M	X/Gxx	M	X	Unknown	Very short M3 (111 and 211) hypocone
SNM/C/1750	M	X/Gxx	M	E+	Zoo Bratislava	Extended periodontitis - moderate in left side
SNM/C/1968	M	X/Gxx	M	E+	Zoo Bratislava	Only M1 (109) worn. Very strange M3 (211) lingual shape. Left ossicone shorter and thinner - No obvious signs of trauma - likely congenital/developed shorter
DNMNH/TM/16431	M	X/Gxx	X	A	Unknown	–
HNHM/77.70.1	M	X/Gxx	X	A	Unknown	–
DNMNH/AZ/2154	M	X/Gxx	X	B	Zoo Pretoria	–
RMCA/RG/8006	M	X/Gxx	X	B	Unknown	–
ZMUA/5047	M	X/Gxx	X	C	Unknown	–

Appendix 2. — Methodology on Age Classes.

Age Class	Actual Age	Age Group	Characteristics
A	< 1	Juvenile	Only deciduous cheek teeth present. Interparietal suture at least partially open. Metopic and coronal sutures open.
B	1–4		Deciduous **and fully erupted adult cheek teeth present**. M1 distal loop closed. Presence of enamel between the paracone and metacone of M1. Pulp cavities of M1 not visible. Interparietal suture at least partially open. Metopic and coronal sutures open.
C	4–6	Adolescent	**Only adult cheek teeth present**. M1 distal loop closed. Presence of enamel between the paracone and metacone of M1. Pulp cavities of M1 not visible. **Interparietal suture closed.** Metopic and coronal sutures open.
D	6–8		Only adult cheek teeth present. M1 distal loop closed. Presence of enamel between the paracone and metacone of M1. Pulp cavities of M1 not visible. Interparietal suture closed. **Metopic and coronal sutures partially closed**.
E	8–11	Adult	Only adult cheek teeth present. M1 distal loop closed. Presence of enamel between the paracone and metacone of M1. Pulp cavities of M1 not visible. Interparietal suture closed. **Metopic and coronal sutures closed**.
F	11–14		Only adult cheek teeth present. **M1 distal loop open.** Presence of enamel between the paracone and metacone of M1. Pulp cavities of M1 not visible. Interparietal suture closed. Metopic and coronal sutures closed.
G	14–17		Only adult cheek teeth present. M1 distal loop open. **Presence of dentine connection between the paracone and metacone of M1.** Pulp cavities of M1 not visible. Interparietal suture closed. Metopic and coronal sutures closed.
H	17–20	Old	Only adult cheek teeth present. M1 distal loop open. **Complete absence of enamel between the paracone and metacone of M1.** Pulp cavities of M1 not visible. Interparietal suture closed. Metopic and coronal sutures closed.
I	> 20		Only adult cheek teeth present. M1 distal loop open. Complete absence of enamel between the paracone and metacone of M1. **Complete absence of enamel and possibly visible pulp cavities of M1**. Interparietal bone not visible. Metopic and coronal sutures closed.

Appendix 3. — Pairwise statistics of the compared groups.

Appendix 3A. — Pairwise statistics using the Fisher's exact p-value of chi-square between the different subspecies concerning dental irregularities, periodontitis, ossicone anomalies and surface anomalies.

Dental Irregularities	***antiquorum***	***camelopardalis***	***peralta***	***angolensis***	***giraffa***	***reticulata***	***thornicrofti***	***tippelskirchi***
antiquorum	–	0.19151	0.090247	1	0.43108	0.79774	0.18167	0.074281
camelopardalis	0.19151	–	0.3326	0.13457	**0.010523**	0.11164	0.71585	0.80917
peralta	0.090247	0.3326	–	0.09732	**0.017473**	0.088765	0.53427	0.35754
angolensis	1	0.13457	0.09732	–	0.57022	1	0.11784	**0.033983**
giraffa	0.43108	**0.010523**	**0.017473**	0.57022	–	0.684	**0.03692**	**0.00031331**
reticulata	0.79774	0.11164	0.088765	1	0.684	–	0.10371	**0.035536**
thornicrofti	0.18167	0.71585	0.53427	0.11784	**0.03692**	0.10371	–	1
tippelskirchi	0.074281	0.80917	0.35754	**0.033983**	**0.000313**	**0.035536**	1	–
Periodontitis	***antiquorum***	***camelopardalis***	***peralta***	***angolensis***	***giraffa***	***reticulata***	***thornicrofti***	***tippelskirchi***
antiquorum	–	0.076785	1	0.15624	**0.013694**	**0.027557**	0.14891	0.16345
camelopardalis	0.076785	–	0.50332	0.83678	0.62442	0.51789	1	0.61118
peralta	1	0.50332	–	0.50988	0.34351	0.29718	0.46467	0.74443
angolensis	0.15624	0.83678	0.50988	–	0.47614	0.48849	1	0.85524
giraffa	**0.013694**	0.62442	0.34351	0.47614	–	0.84672	0.81461	0.1821
reticulata	**0.027557**	0.51789	0.29718	0.48849	0.84672	–	0.78167	0.23459
thornicrofti	0.14891	1	0.46467	1	0.81461	0.78167	–	0.80722
tippelskirchi	0.16345	0.61118	0.74443	0.85524	0.1821	0.23459	0.80722	–
Ossicones	***antiquorum***	***camelopardalis***	***peralta***	***angolensis***	***giraffa***	***reticulata***	***thornicrofti***	***tippelskirchi***
antiquorum	–	0.69547	0.067648	0.16248	0.36544	1	1	1
camelopardalis	0.69547	–	0.12646	0.35985	0.61733	0.7019	1	0.50853
peralta	0.067648	0.12646	–	0.40751	0.17359	0.085325	0.10553	**0.036712**
angolensis	0.16248	0.35985	0.40751	–	0.60297	0.28428	0.25463	0.050865
giraffa	0.36544	0.61733	0.17359	0.60297	–	0.36613	0.46695	0.10696
reticulata	1	0.7019	0.085325	0.28428	0.36613	–	1	1
thornicrofti	1	1	0.10553	0.25463	0.46695	1	–	1
tippelskirchi	1	0.50853	**0.036712**	0.050865	0.10696	1	1	–

Appendix 3A. — Continuation.

Surface Anomalies	*antiquorum*	*camelopardalis*	*peralta*	*angolensis*	*giraffa*	*reticulata*	*thornicrofti*	*tippelskirchi*
antiquorum	–	1	1	0.59782	0.62967	0.49452	1	0.65058
camelopardalis	1	–	1	1	1	0.52038	1	1
peralta	1	1	–	1	1	1	1	1
angolensis	0.59782	1	1	–	1	1	1	0.050865
giraffa	0.62967	1	1	1	–	0.57668	1	1
reticulata	0.49452	0.52038	1	1	0.57668	–	0.38182	0.57244
thornicrofti	1	1	1	1	1	0.38182	–	1
tippelskirchi	0.65058	1	1	0.050865	1	0.57244	1	–

Appendix 3B. — Pairwise statistics using the Fisher's exact p-value of chi-square between the different species concerning dental irregularities, periodontitis, ossicone anomalies and surface anomalies.

Dental Irregularities	*camelopardalis*	*giraffa*	*reticulata*	*tippelskirchi*
camelopardalis	–	**0.000088741**	0.14596	0.28432
giraffa	**0.000088741**	–	0.33708	**<0.000001**
reticulata	0.14596	0.33708	–	**0.031685**
tippelskirchi	0.28432	**<0.000001**	**0.031685**	–
Periodontitis	***camelopardalis***	***giraffa***	***reticulata***	***tippelskirchi***
camelopardalis	–	0.14479	0.11418	0.59522
giraffa	0.14479	–	0.57332	0. 41419
reticulata	0.11418	0.57332	–	0.24666
tippelskirchi	0.59522	0.41419	0.24666	–
Ossicones	***camelopardalis***	***giraffa***	***reticulata***	***tippelskirchi***
camelopardalis	–	0.58407	0.73781	0.15888
giraffa	0.58407	–	0. 38358	**0.032785**
reticulata	0.73781	0.38358	–	1
tippelskirchi	0.15888	**0.032785**	1	–
Surface Anomalies	***camelopardalis***	***giraffa***	***reticulata***	***tippelskirchi***
camelopardalis	–	0.52031	0.58898	1
giraffa	0.52031	–	1	0.74698
reticulata	0.58898	1	–	0.58469
tippelskirchi	1	0.74698	0.58469	–

Appendix 3C — Pairwise statistics using the Fisher's exact p-value of chi-square between the North *Giraffa camelopardalis* (Linnaeus, 1758) and *G. reticulata* de Winton, 1899) and South (*G. giraffa* (Boddaert, 1784) and *G. tippelskirchi* Matschie, 1898) groups concerning dental irregularities, periodontitis, ossicone anomalies and surface anomalies.

Dental Irregularities	North	South
North	–	0.061027
South	0.061027	–
Periodontitis	**North**	**South**
North	–	0.30804
South	0.30804	–
Ossicones	**North**	**South**
North	–	0.86734
South	0.86734	–
Surface Anomalies	**North**	**South**
North	–	1
South	1	–

Appendix 3D. — Pairwise statistics using the Fisher's exact p-value of chi-square between sexes concerning dental irregularities, periodontitis, ossicone anomalies and surface anomalies.

Dental Irregularities	Males	Females
Males	–	0.73231
Females	0.73231	–
Periodontitis	**Males**	**Females**
Males	–	0.77111
Females	0.77111	–
Ossicones	**Males**	**Females**
Males	–	**0.00018188**
Females	**0.00018188**	–
Surface Anomalies	**Males**	**Females**
Males	–	0.10408
Females	0.10408	–

Appendix 3E. — Pairwise statistics using the Fisher's exact p-value of chi-square between the different age classes concerning dental irregularities, periodontitis, ossicone anomalies and surface anomalies.

Dental Irregularities	A	B	C	D	E	F	G	H	I
A	–	1	**0.0392**	**0.0032**	**< 0.0001**	**< 0.0001**	**0.0042**	**0.0392**	0.1020
B	1	–	**0.0206**	**0.0007**	**< 0.0001**	**< 0.0001**	**0.0010**	**0.0206**	0.0656
C	**0.0392**	**0.0206**	–	0.7361	0.1789	0.1762	1	1	1
D	**0.0032**	**0.0007**	0.7361	–	0.1731	0.1711	1	0.7361	0.4829
E	**0.0001**	**< 0.0001**	0.1789	0.1731	–	0.8911	0.0880	0.1789	0.0890
F	**0.0001**	**< 0.0001**	0.1762	0.1711	0.8911	–	0.1206	0.1762	0.0906
G	**0.0042**	**0.0010**	1	1	0.0880	0.1206	–	1	0.7099
H	**0.0392**	**0.0206**	1	0.7361	0.1789	0.1762	1	–	1
I	0.1020	0.0656	1	0.4829	0.0890	0.0906	0.7099	1	–

Periodontitis	A	B	C	D	E	F	G	H	I
A	–	1	**0.0010**	**0.0068**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**
B	1	–	**0.0003**	**0.0016**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**
C	**0.0010**	**0.0003**	–	0.3273	1	0.0725	**0.0113**	**0.01759**	**0.0019**
D	**0.0068**	**0.0016**	0.3273	–	0.0815	**< 0.0001**	**< 0.0001**	**0.0001**	**< 0.0001**
E	**0.0001**	**< 0.0001**	1	0.0815	–	**0.0006**	**0.0001**	**0.0013**	**< 0.0001**
F	**< 0.0001**	**< 0.0001**	0.0725	**< 0.0001**	**0.0006**	–	0.2015	0.1278	**0.0277**
G	**< 0.0001**	**< 0.0001**	**0.0113**	**< 0.0001**	**0.0001**	0.2015	–	0.7552	0.1992
H	**< 0.0001**	**< 0.0001**	**0.0176**	**< 0.0001**	**0.0013**	0.1278	0.7552	–	0.6602
I	**< 0.0001**	**< 0.0001**	**0.0019**	**< 0.0001**	**< 0.0001**	**0.0277**	0.1992	0.6602	–

Ossicones	A	B	C	D	E	F	G	H	I
A	–	1	1	1	**0.0138**	**0.0231**	**0.0330**	**0.0392**	0.3265
B	1	–	1	1	**0.0022**	**0.0064**	**0.0113**	**0.0206**	0.262
C	1	1	–	1	0.1315	0.1250	0.1665	0.2286	0.4706
D	1	1	1	–	**0.0042**	**0.0067**	**0.0263**	**0.0265**	0.2857
E	**0.0138**	**0.0022**	0.1315	**0.0042**	–	0.8569	1	1	0.4678
F	**0.0231**	**0.0064**	0.1250	**0.0067**	0.8569	–	1	0.731	0.6946
G	**0.0330**	**0.0113**	0.1665	**0.0263**	1	1	–	1	0.6614
H	**0.0392**	**0.0206**	0.2286	**0.0265**	1	0.731	1	–	0.6041
I	0.3265	0.2623	0.4706	0.2857	0.4678	0.6946	0.6614	0.6041	

Surface Anomalies	A	B	C	D	E	F	G	H	I
A	–	1	1	1	1	1	0.5021	1	0.3265
B	1	–	1	1	1	1	0.6121	1	0.4590
C	1	1	–	1	1	1	1	1	0.4706
D	1	1	1	–	0.5729	1	1	1	0.4935
E	1	1	1	0.5729	–	0.6690	0.2759	1	0.3091
F	1	1	1	1	0.6690	–	0.6204	1	0.4232
G	0.5021	0.6121	1	1	0.2759	0.6204	–	1	1
H	1	1	1	1	1	1	1	–	0.4706
I	0.3265	0.4590	0.4706	0.4935	0.3091	0.4232	1	0.4706	–

Appendix 3F. — Pairwise statistics using the Fisher's exact p-value of chi-square between the different age groups concerning dental irregularities, periodontitis, ossicone anomalies and surface anomalies.

Dental Irregularities	Juvenile	Adolescent	Adult	Old
Juvenile	–	**0.000017583**	**<0.000001**	**0.0020742**
Adolescent	**0.000017583**	–	0.062549	0.58361
Adult	**<0.000001**	0.062549	–	**0.03043**
Old	**0.0020742**	0.58361	**0.03043**	–

Periodontitis	Juvenile	Adolescent	Adult	Old
Juvenile	–	**0.0000023864**	**<0.000001**	**<0.000001**
Adolescent	**0.0000023864**	–	**0.00043242**	**<0.000001**
Adult	**<0.000001**	**0.00043242**	–	**0.00039264**
Old	**<0.000001**	**<0.000001**	**0.00039264**	–

Ossicones	Juvenile	Adolescent	Adult	Old
Juvenile	–	1	**0.000028533**	**0.007467**
Adolescent	1	–	**0.00030763**	**0.016598**
Adult	**0.000028533**	**0.00030763**	–	**0.79875**
Old	**0.007467**	**0.016598**	**0.79875**	–

Surface Anomalies	Juvenile	Adolescent	Adult	Old
Juvenile	–	1	1	0.21824
Adolescent	1	–	1	0.55246
Adult	1	1	–	0.21493
Old	0.21824	0.55246	0.21493	–