



18. ISDM 3. IAPO

International Symposium
on Dental Morphology

Congress of the International
Association for Paleodontology

Tuesday, 16.8.2022

**Dental Evolution
and Phylogeny**

**Dental Development
and Growth**

**Dental Morphology
and Morphometrics**

von Koenigswald Lecture

T. Bromage

Toward a Metabolic Theory of Paleoecology,
Liberating the Unknowable in Paleobiomics

Wednesday, 17.8.2022

**Dental Morphology
and Morphometrics**

**Dental Life History
and Ecology**

Poster Session



detailed programme
available here

Thursday, 18.8.2022

**Dental Biomechanics
and Evolutionary
Dentistry**

Dental Forensics

Poster Session

Conference Dinner

Friday, 19.8.2022

**Excursion, Messel Pit and HLMD (Hesse State
Museum Darmstadt)**

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Welcome Letter

Dear Friends and Colleagues,

On behalf of the organizing committee, it is a great pleasure and honour for me to welcome you to the 18th International Symposium on Dental Morphology (ISDM) and the 3rd congress of the International Association of the Palaeodontology (IAPO) from August 15th – 19th, 2022 at the Senckenberg Research Institute and Natural History Museum in Frankfurt am Main, Germany. At the last ISDM at the University of Bordeaux, France, in 2017, the headquarters of Senckenberg – Leibniz Institution for Biodiversity and Earth System Research was chosen as the venue for the present ISDM conference. After two postponements due to the Corona pandemic, we are delighted to host the 18th ISDM in Frankfurt am Main.

The *Senckenberg Gesellschaft für Naturforschung* (SGN) was established in 1817 by local citizens in Frankfurt am Main. With a long tradition of integrative approaches to geobiodiversity, Senckenberg in Frankfurt is one of the world-renowned European natural history museums, and one of the largest. Today, the SGN operates seven research institutes and three natural history museums in Germany. The museums are located in Frankfurt, Görlitz, and Dresden. Senckenberg conducts and supports research in many fields of Geo- and Biosciences, and transmits knowledge through publications, education, museum exhibitions and events.

After more than 50 years, starting with its first conference in 1965 in Fredensborg, Denmark, the International Symposium on Dental Morphology (ISDM) is and shall remain an independent, interdisciplinary conference gathering world specialists in dental research contributing to the fields of Anthropology, Palaeoanthropology, Palaeontology, Zoology, Molecular Biology, Anatomy, Archaeology, Biomechanics, Forensics, Dentistry and Orthodontics. Usually we come together for three to four days every three years to discuss intensively the latest scientific results and diverse current research perspectives on dental evolution, adaptations in the jaw-system, tooth development, tooth growth, life history, functional morphology, evolutionary dentistry and dental forensics in our unique forum.

The program is organized into scientific sessions with oral and poster presentations on dental evolution and phylogeny, dental development and growth, dental morphology and morphometrics, dental life history and ecology, dental biomechanics and evolutionary dentistry, dental genetics and dental forensics.

The scientific program is complemented by social events and the annual public Gustav Heinrich Ralph von Koenigswald Lecture, entitled *Toward a Metabolic Theory of Paleoecology, Liberating the Unknowable in Paleobiomics* delivered by Timothy Bromage. On the final day there will be an excursion with visits to a UNESCO World Heritage Site, the *Eocene Messel Pit Fossil Site*, and the arts and cultural history and natural history exhibitions of the Hessisches Landesmuseum in Darmstadt.

All organizing committee members warmly welcome all participants to the 18th ISDM and the 3rd IAPO, and wish you an enjoyable and memorable stay in Frankfurt.

Yours, on behalf of the organizing committee,

Ottmar Kullmer

Scientific Board 18th ISDM 3rd IAPO 2022

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THE ROLE
OF CULTURE
IN EARLY
EXPANSIONS
OF HUMANS

Programme

MONDAY, 15.08.2022	
17.00	Arrival, Registration Informal Welcome <i>Dinosaur hall at the Senckenberg Museum</i>

TUESDAY, 16.08.2022			
8.30		Registration	
9.30		Opening	
Dental Evolution and Phylogeny			
<i>Chair: Julia Schultz, Irina Ruf</i>			
9.45	O01	The developmental basis of 200-million-year-old stem-mammal teeth	Corfe et al.
10.05	O02	Evolutionary allometry of upper molar proportions in placental mammals	Billet, Bardin
10.25	O03	Interest of studying the evolution of dental eruption patterns in placental mammals	Gomes Rodrigues
Coffee break			
11.15	O04	Anteriorly directed molar occlusal movement during the power stroke is unique to therian mammals and may have spurred dietary diversification	Schultz et al.
11.35	O05	Modifications of the anterior dentition in mammals	von Koenigswald
11.55	O06	Evolution of <i>Paranthropus robustus</i> posterior teeth in association with aridification and a more mechanically challenging diet across time	O'Hara et al.
12.15	O07	The Middle Paleolithic Populations of the Levant: A Dental Perspective	Sarig
Lunch break			
Dental Development and Growth			
<i>Chair: Horst Kierdorf</i>			
14.00	O08	Embryology and Homology in the Mammalian Dentition	Asher
14.20	O09	Integrating the regulation of patterning and growth in the scaling of mammalian teeth	Jernvall, Christensen
14.40	O10	Accentuated lines in primary dental enamel in Polish children with autism and Down syndrome	Kurek et al.
Dental Morphology and Morphometrics			
<i>Chair: Luca Fiorenza, Clément Zanolli, Matthew Skinner</i>			
15.00	O11	Acute or obtuse? Towards a universal classification of lophed cheek teeth	Žliobaitė, Fortelius
15.20	O12	Possible phylogenetic influence on carnassial functionality as revealed by 3D geometric morphometrics	Lang, Martin

Coffee break			
16.10	O13	Functional analysis of the dentition of <i>Lesmesodon</i> (Mammalia, Hyaenodonta)	Weidtke et al.
16.30	O14	Morphological and morphometric comparison of the first lower molar in Pantherinae (Felidae, Mammalia)	Wirkner et al.
16.50	Conference Photo		
19.30	Gustav Heinrich Ralph von Koenigswald Lecture <i>Toward a Metabolic Theory of Paleoecology, Liberating the Unknowable Paleobiomics</i>		Bromage
22.00	End of the Day		

WEDNESDAY, 17.08.2022			
Dental Morphology and Morphometrics			
Chair: Luca Fiorenza, Clément Zanolli, Matthew Skinner			
9.00	O15	Loph morphologies and diet in cercopithecids	Walker et al.
9.20	O16	Exploring the dental toolkit of primates using dental topography and the doolkit package	Thiery et al.
9.40	O17	New approach to assess the relationship between macrowear and enamel thickness in lower first molars.	Oxilia et al.
10.00	O18	The frequency of taurodontism in the historical population of Radom (11th-19th centuries).	Pach et al. (Tomczyk)
10.20	O19	Dental metric on the Late Holocene to Current Era Population from the Lowland part of Indonesian-Papua	Tolla et al.
10.40	O20	The Evolutionary Changes in Molar's Root Morphology in Holocene Levantine Populations	Bader Farraj, Sarig
Coffee break			
11.30	O21	Dental morphological indicators of Native Mexican Ancestry are associated with greater cranial fluctuating asymmetry in Colonial Mexico City.	Edgar et al.
11.50	O22	A 2D geometrical morphometric model of the lower third molar of the archaeological dwarf deer from Pedro Gonzalez Island (Panama)	Martínez-Polanco et al.
12.10	O23	Comparing Biodistance Estimates from Deciduous and Permanent Dental Morphology in a Sample from the Pre-Hispanic Southwest United States	Moes, O'Donnell
12.30	O24	Solving the <i>Hemantropus peii</i> mystery	Zanolli et al.
Lunch break			
Dental Life History and Ecology			
Chair: Kurt Alt, Luca Bondioli			

14.00	O25	Comparison of crown growth parameters in molars of <i>Hippopotamus minor</i> and <i>H. amphibius</i> based on incremental markings in enamel	Kierdorf H et al.
14.20	O26	Trace element profiles in enamel from histologically-controlled laser-based mass spectrometry reveal dietary cyclicity in <i>Pongo</i> and <i>Homo erectus</i> from Sangiran	Kubat et al.
14.40	O27	Effects of Vitamin D deficiency on tooth mineral density and chemical composition	Beckett et al. (Loch Silva)
15.00	O28	Dietary Reconstruction of Levantine Holocene Populations based on Dental Microwear texture	Megreli et al. (Sarig)
15.20	O29	Problematic breastfeeding practices in two post-medieval finnish towns according to $\Delta^{15}N$ and $\Delta^{13}C$ analyses of archaeological dentin	Väre
15.40	O30	Determination of Dental Age and Diet in the Illyrian Population from the Kopila necropolis on the Island of Korčula, Croatia	Marić et al. (Vodanović)
Coffee break			
16.30	Poster Session/Visit the fossil hominins		
17.30	End of the Day		

THURSDAY, 18.08.2022			
Dental Biomechanics and Evolutionary Dentistry			
<i>Chair: Ellen Schulz-Kornas, Cinzia Fornai, Rachel Sarig</i>			
9.00	O31	The tricondont molar form and function	Jäger et al.
9.20	O32	Jaw mechanics in shrews and the role of the double articulation	Pommerening , Martin
9.40	O33	Dental microwear texture analysis of rats receiving near-natural diets shows that seeds and insect exoskeletons cause high enamel surface complexity	Winkler et al.
10.00	O34	The effect of force directionality and magnitude on dental enamel wear	Habashi , Sarig
Coffee break			
10.50	O35	The Morphology of Non-Carious Cervical Lesions: What Can It Teach Us?	Dassa , Sarig
11.10	O36	Facial asymmetry and chewing sides in twins	Heikkinen et al.
11.30	O37	Quo vadis wear and 3D surface texture - bridging applications in paleoanthropology, archeology, biology and dentistry	Schulz-Kornas
11.50	O38	Craniomandibular dysfunctions as consequence of civilization	Fornai et al.
12.10	O39	Modeling the histogenetic switch from enameloid to enamel	Houée et al.
Lunch Break			

Dental Forensics			
Chair: Marin Vodanović			
13.50	O40	Automated personal identification based on tooth enamel microstructure	Bressan Fogalli et al.
14.10	O42	Color Change in Teeth Due to Burning: Spectrophotometric Measurement	Peer, Sarig
14.30	O43	Pathogenesis and Lines of Salter: insights into the biology of dental cementum for forensic applications.	Perrone et al.
14.50	O44	Micro-CT-investigation of rare dental anomalies in two sympatric European bat species (<i>Pipistrellus</i> spp.)	Rabenstein, Stiefel
15.10		Final discussion	
Coffee break			
15.50		Poster Session/Visit the fossil hominins	
19.00		Conference Dinner	
22.00		End of the Day	

FRIDAY, 19.08.2022	
8.30 – 19.00	Excursion: Messel Pit Fossil Site and HLMD (Hesse State Museum Darmstadt)

List of posters

P01	Patterns of incisor and first permanent molar development in modern humans, great apes and early fossil hominins.	Dean et al.
P02	Chronology of the medieval population of Gevensleben assessed by dental enamel microdefects	Storsberg et al.
P03	Testing the presence of sexual dimorphism in radicular dentine thickness and topographic distribution in modern human upper permanent canines	Augoyard et al.
P04	Wild boar vs domestic pigs – A deep dive into tooth crown formation	Emken et al.
P05	Marked discrepancy between dental and skeletal development associated with pathological conditions: a case report	Fauth, Witzel
P06	Facial asymmetry and chewing sides in twins	Heikkinen et al.
P07	New analysis of Nolla's longitudinal radiographic study.	Lim et al.
P08	The association between Retzius periodicity and adult height in modern New Zealanders.	McFarlane et al.
P09	Perinatal tooth eruption in precocial and altricial rodents and lagomorphs	Ruf
P11	Accessory cusp expression in hominoid mandibular molars	Davies
P12	Effective low-cost high-resolution replicas for light scanning and topographic analysis of dental crown.	Estalrich et al.
P13	Looking below the surface of highly complex Cave Bear Molars	George Varghese et al.

P14	In hypodontia some morphological parameters of premolars and molars vary with different sites of the congenitally missing teeth	Kerekes-Máthé et al.
P15	The evolutionary transition from the second to the first molar dominance	Meschiany Sabag et al. (Sarig)
P16	Cusp 6: world variation on the lower first and second molars and possible link to EDAR v370a	Pastore, Scott
P17	Kinship and mortuary practices at the ancient Greek colony of Chersonesos (Crimea): Insights from dental morphology	Rathmann et al.
P18	Easter Island: what does dental morphology tell us about possible biological impact from the Americas	Scott, Walbrecker
P19	Maxillary lateral incisor mesial bending in Medieval populations from the Iberian Peninsula	Hernández Canales et al. (Silva)
P20	The co-occurrence of rare nonmetric dental traits in Middle Holocene burials from Toca do Enoque support intrasite family relationships	Solari et al.
P21	Tip of lower incisors of rodents: measurements of the angle of the lower incisor tip as wedge angle	Stefen
P22	Standardization of dental complexity measurements using OPC	Stenberg et al.
P23	A distance-based comparison method for measuring occlusal tooth wear from dental 3D models	Vuollo et al.
P25	Life history in the primate skeleton is revealed by changes in major and minor element concentrations measured via field-emission SEM-EDS	Cerrito et al.
P26	Characterization of abnormal cheek tooth wear in fluorotic dentitions of the European roe deer (<i>Capreolus capreolus</i>)	Kierdorf U, Kierdorf H
P27	Non-occlusal dental microwear texture analysis of a somphospondyli titanosauriform sauropod dinosaur from the Tamagawa Formation, northeastern Japan.	Kubo T et al.
P28	Interrelationship among dental wear proxies in the extant sika deer with known ecology	Kubo M, Winkler
P29	Short and long term dietary analyses as a means of evaluating social relationships in the pre-Colonial Middle Ohio River Valley, USA	Lagan et al.
P30	Functional Morphology of Hyracoid Dentition	Losco
P31	The rate of dental wear for the prehistoric hunter-gatherers in Japan	Nakamura, Kondo
P32	Time-resolved variations of trace elements in dental enamel discriminates between breastfed and formula-fed infants in children with known dietary history	Nava et al.
P33	Hunter-gatherer in transformation: a study of two Terminal Pleistocene - Holocene molars from the South-eastern corner of Sundaland	Noerwidi et al.
P34	Dental wear patterns reveal dietary and environmental history in a Western chimpanzee population from Liberia	Stuhlträger et al.
P35	Fossil enamel proteomics: the role of amelogenin peptides in sexing ancient humans and animals	Lugli et al.
P36	Finite Element Analysis of Le Moustier 1 maxillary incisors	Najafzadeh et al. (Fiorenza)
P37	Rates of dental shape changes with age in African rainforest hunter-gatherers	Romero et al.
P38	How is the occlusal morphology established in human molars?	Sova et al.
P39	A case of impacted third molar from the prehistoric hypogeum of Calaforno (Sicily): reflections on the antiquity and evolutionary implications of this ancestral trait	Kurek et al.

Abstracts of the 18th International Symposium on Dental Morphology and 3rd Congress of the International Association for Paleodontology, August 15 – 19, 2022, Frankfurt, Germany

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Oral presentations

Abstracts are ordered as in the meeting programme.

Dental Evolution and Phylogeny

O01

The developmental basis of 200-million-year-old stem-mammal teeth

Ian Corfe (1,2), Andrew Conith (3), Teemu J Häkkinen (4), Pam Gill (5,6), Jukka Jernvall (1)

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The limited preservation of genetic data and records of development in fossils make applying insights from biological developmental genetics to extinct animals difficult. Fossils though provide data on morphological variation, which can be studied from a developmental perspective. We tested whether variation in fossil mammal tooth shape can be used to identify its molecular/developmental origins. To examine the developmental potential of teeth in early mammalian evolution, we quantified developmentally informative shape variation in the 200Ma old Early Jurassic stem-mammal *Morganucodon*. Comparing results with similarly shaped extant seal, lynx, marten, and raccoon dog dentitions shows *Morganucodon* has both a) tooth shape variation, and b) correlation of anterior-posterior cusp variation, intermediate between seals (with high variation/correlation, having lost well-defined tooth occlusion in shifting to a piscivorous diet) and other carnivorans (low variation/correlation). We interpret that *Morganucodon*'s intermediate variation and partially decoupled anterior-posterior correlation represent early stages of the developmental control required for precise mammalian occlusion, adding to studies showing *Morganucodon* and related stem-mammals with diphyodonty and incipiently precise upper-lower tooththrow occlusion first evolved in the Late Triassic-Early Jurassic. Next we used a gene-network/tissue-mechanic computational model of tooth development to infer likely genetic/developmental changes underlying the evolution of modern mammalian occlusion. Analysing virtual seal and *Morganucodon* teeth, we found varying most developmental parameters lead to correlated anterior/posterior variation. These parameters are linked to known, experimentally validated molecular/genetic candidates. However, the few parameters producing uncorrelated variation, necessary for modern mammals complex tooth shapes and tight occlusion, are poorly understood. This study shows fossils can provide data for understanding the basis of morphological diversity, and help direct future molecular research.

O02

Evolutionary allometry of upper molar proportions in placental mammals

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Repeated segments such as limbs or teeth are a widespread characteristic of organisms. Recent research has suggested that the proportions of each segment within a series may be governed by similar developmental rules in vertebrates. Within the dentition, the proportions of molars show a strong linear relationship, which is well-explained by the Inhibitory Cascade model of molar development described in mice. While studies of molar proportions gained much interest after the emergence of this model, there was only limited investigation regarding a possible allometric patterning within the molar row. Placental mammals repeatedly evolved a wide range of body size in their history, and since variation in size constitutes an important determinant for variation in biological traits, it may be seen as surprising that so few allometric trends have been documented on placental molars so far. Here, we analyzed the diversity of upper molar proportions in relation to absolute size in a large sample of placental mammals (both extant and extinct species) representing most of the group’s dental diversity. Our phylogenetically informed analyses revealed a 2-fold pattern of evolutionary integration among upper molars: while molars covary in size with each other, their proportions covary with the absolute size of the entire molar field. With increasing absolute size, posterior molars increase in size relative to anterior ones, i.e. large-sized species have relatively large rear molars. The opposite is true for small-sized species. This allometric patterning in the directionality of proportional increase in the molar row shows how large-scale variations in size may have influenced variation in dental morphology. It further suggests that processes regulating the size of individual molars are integrated with overall patterns of growth and calls for further testing of allometric variation in the dentition.

Keywords: cheek teeth; size; diversity; evolution; inhibitory cascade model

O03

Interest of studying the evolution of dental eruption patterns in placental mammals

Helder Gomes Rodrigues

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Numerous studies on extant mammalian species suggest that a tight relationship might exist between ontogenetic dental traits, ecological traits and life-history traits, the latter often being difficult to assess in extinct species. Among these dental traits, modifications affecting dental growth and eruption are thought to be associated with changes in feeding habits, growth rates or longevity. Prolonged dental growth characterised by crown height increase (or hypsodonty) has been extensively studied in extinct forms in relation to major environmental changes during the Cenozoic. Changes associated with the sequence of dental eruption (i.e. eruption of permanent premolars versus molars) are conversely poorly studied in extinct mammals, despite the palaeoecological, palaeobiological and phylogenetic interests they might represent. I studied the evolution of these dental eruption patterns in different groups of large herbivorous mammals such as the "native South American ungulates" (Notoungulata, Astrapotheria), Cetartiodactyla and Perissodactyla. I showed that the evolution of these patterns was very dissimilar from one group to another and that it could be associated with different parameters (e.g. hypsodonty, body mass) and in relation or not with environmental variations. These results also allowed me to propose paleoecological (e.g. diet) and paleobiological (e.g. growth rate) hypotheses that will be the subject of future studies to better understand the putative ecological and biological adaptations of herbivorous mammals to environmental variations.

O04

Anteriorly directed molar occlusal movement during the power stroke is unique to therian mammals and may have spurred dietary diversification

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Mammals differ from most vertebrates in having precise dental occlusion, a lower jaw composed of one bone, and middle ear ossicles derived from ancestral jaw bones. Non-mammalian synapsids and early mammals underwent complex evolutionary changes in both feeding and hearing adaptations, which were crucial for the radiation of extant mammals. In order to investigate functional transitions in the chewing mechanisms of synapsids, we compiled jaw movement directions during postcanine occlusion based on primary literature for a sample of 133 synapsid genera. Results of our meta-analysis indicate that occlusal complexity generally increases in more recently evolved synapsid clades, but occlusal movements among non-therian synapsids are limited to orthal-dominated shearing processes with some taxa that developed palinal chewing movements. Therian mammals are the only synapsids that exhibit occlusal movements with a significant anterior component, and they also are a very diverse clade in terms of occlusal functions, exhibiting an incredible range of diets and dental morphologies. An anteriorly directed jaw movement during occlusion necessitates anteriorly directed muscle force vectors. We posit that such muscular change is achieved by the appearance of the cladotherian angular process that shifts the orientation of superficial masseter and medial pterygoid muscles. The evolutionary change in jaw morphology and muscular adjustment was followed by the appearance of the lower molar talonid basin, which facilitates additional occlusal contacts during extended transverse movements. In earlier synapsids, the middle ear elements were connected to the lower jaw and likely prohibited the more posterior insertion of jaw musculature and thus a pronounced anterior jaw movement. Thus, the complex shift in the entire masticatory apparatus of early cladotherians, involving jaw corpus and muscles, molar shape, and detachment of the middle ear elements permitted novel masticatory movements later in evolution. The ability of early cladotherians and therians to perform jaw movements with precise occlusion during complex chewing cycles was an important advancement for the upcoming tribosphenic molar, which is considered to be the ancestral molar type of all extant therians. This molar type permitted access to a broader range of diets. In combination with the evolution of anteriorly directed occlusion, this might have set the stage for the dietary and occlusal diversity observed among extant therian mammals.

O05

Modifications of the anterior dentition in mammals

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During evolution, mammals diversified their anterior dentition extensively. They produced various constellations of incisors and canines. These constellations, however, reoccur in disparate mammalian groups due to parallel evolution. This is why the postcanine dentition is preferred in phylogenetic reconstructions. Modifications of the anterior dentition represent stages of a stepwise reduction of some tooth positions and enlargement of others. As a result, specific constellations occur repeatedly. The various constellations are characterized by

- the presence or absence of specific tooth positions
- the enlargement of specific tooth positions
- similar occurrences in the upper and lower dentition (conformable)
- major differences between upper and lower dentition (disparate)

A classification of constellations should not be an end in itself. On the contrary, careful classification allows functional comparisons between taxa. Furthermore, changing constellations during the evolution of a specific group provide additional insights. From some 20 constellations identified here, some occur in large mammals and others predominantly in small mammals.

Some taxa preserve a characteristic anterior dentition for a long time in their history, such as Rodentia with a single pair of incisors. Other groups, e. g., Carnivora, have a predominant constellation (full number of incisors and moderately enlarged canines) even if exceptions may occur (enlarged upper canines or tusks). The anterior dentition of Artiodactyla takes several forms: Suiformes have enlarged canines, but other groups have small or reduced, canines. Ruminant artiodactyls have an incisor arcade (RIA) with small incisiform lower canines and no antagonistic teeth in the premaxilla. Some Xenarthra lack incisors in the upper and lower jaw.

In the human dentition the significance of conformable incisors for cutting food is obvious. Reduction of the anterior dentition in other mammalian lineages indicates the increasing functional dependence on lips for grasping food. Although lips are never preserved in fossils, the absence of incisors indicates a dependence on specialized lips.

O06

Evolution of *Paranthropus robustus* posterior teeth in association with aridification and a more mechanically challenging diet across time

Mackie C O'Hara (1), Simon Chapple (1), Mark Hubbe (2), Patrick Mahoney (1), W Scott McGraw (2), Gary T Schwartz (3), Matthew M Skinner (1,4), Debbie Guatelli-Steinberg (2,1)

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A recent examination of *P. robustus* crania revealed temporal trends such that younger specimens are characterized by larger teeth and more anteriorly positioned sagittal crests and zygomatic roots, features argued to be associated with the production of high bite forces. A simultaneous drying period and expansion of shrubland-type vegetation led to the conclusion that *P. robustus* concomitantly adapted to an increasingly mechanically-challenging diet.

Here, we test whether the dental form of *P. robustus* followed a similar evolutionary trajectory. Digital 2D slices through the central (premolars) and mesial (molars) cusps of *P. robustus* lower first and second molars (n=16), upper first and second molars (n=14), upper third premolars (UP3, n= 11), and upper fourth premolars (UP4, n=13) were generated, representing approximately 1 million years of *P. robustus* evolution. Each slice was evaluated for tooth shape, tooth size, overall enamel thickness, and regional enamel distribution metrics. Jonckheere-Terpstra tests were performed to identify trends in each measurement.

All postcanine teeth reported at least one significant temporal trend that matched what would be expected for adaptations to mechanically-challenging diets, such as thicker enamel. Most notably, *P. robustus* UP4s showed significant trends in 14 measurements, increasing in size, strength, AET, and occlusal enamel thickness. This increase in UP4 crown size may relate to increasing molarization.

P. robustus underwent rapid evolution in cranial and dental form in response to environmental and dietary shifts. While enamel thickness measures were the most frequently identified changes, aspects of tooth size and shape also shifted in UP4s and upper molars. This suggests that the dental form of different tooth types (molars and premolars) and tooth positions (UP3s vs UP4s) may evolve at different rates. *P. robustus* UP4s underwent a massive transformation, while UP3s, upper molars, and lower molars showed relatively fewer shifts in their dental form over the same time period.

O07

The Middle Paleolithic Populations of the Levant: A Dental Perspective

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The Middle Paleolithic is one of the most significant periods in human evolutionary history as different *Homo* groups were occupying near-by lands contemporaneously. One of the greatest challenges is to reveal the taxonomic status of these populations and expose their relationships. The Levant is a non-parallel source of information for studying this unique period in human history, presenting abundant of fossils from the entire Middle Paleolithic (ca. 250-50 ka).

In recent years, several excavations of prehistoric sites in Israel yielded new fossils, allowing us to re-evaluate and expose the dynamic relationships between the Levantine Middle Paleolithic *Homo* groups. In the current study, we will focus on the dental remains retrieved in these sites. All teeth were analyzed using classic morphological and 3D geometric morphometric methods. The study sample included the dental remains from Qesem, Tabun, Misliya, Qafzeh, and Skhul caves and from the recently discovered Neshel-Ramla open air-site.

The findings demonstrated a resemblance between the Neshel-Ramla and Qesem teeth, and morphological differences between the Misliya teeth and the Qafzeh and Skhul teeth. Based on our results, we suggest that the Levant during the Middle Paleolithic was occupied by at least three *Homo* groups (paleodems) which could indicate the presence of a hybrid population.

Dental Development and Growth

O08

Embryology and Homology in the Mammalian Dentition

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Macroscelidid afrotherians and canid carnivorans possess four premolar loci, the first of which is not replaced. Previous work suggests that the first premolar in macroscelidids is a retained deciduous tooth, but in *Canis* it is a successional tooth with no milk precursor. We tested this contrasting interpretation of first premolar homology with data from ontogenetic anatomy and with area predictions from the inhibitory cascade (IC) model. Our results based on anatomy support previous interpretations that the functional first premolar is a retained deciduous tooth (dp1) with no successor in macroscelidids, and a successional tooth (p1) with no precursor in *Canis*. Hyracoids are among the few placental mammals that show replacement at the first premolar locus and show less deviation than other taxa of actual from predicted areas across the deciduous and molar toothrow. However, predicted vs. actual tooth areas can depart substantially from one another. At least without a better means of representing tooth size, the inhibitory cascade does not help to distinguish the deciduous from successional first premolar. This observation does not rule out the possibility that factors such as a size-shift within the toothrow (e.g., carnivoran carnassials) help to explain deviations from the inhibitory cascade model.

O09

Integrating the regulation of patterning and growth in the scaling of mammalian teeth

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When evolution leads to differences in body size, sizes of organs generally scale along. A well-known example of the tight relationship between organ and body size is the scaling of mammalian molar teeth. To investigate how teeth scale, we compared the development of size and shape of the first lower molar in the mouse and the rat. The linear dimensions of the rat molar are twice that of the mouse molar, but their shapes are roughly the same. We discovered that scaling of the teeth is active already during the initiation of tooth cusp development, and as a result, the rat molar is patterned in a larger size than the mouse molar. Using transcriptomics, ex vivo and in vivo mouse experiments, computational modelling, and comparative data from several species, we will show how patterning and growth are integrated in the scaling of mammalian teeth.

O10

Accentuated lines in primary dental enamel in Polish children with autism and Down syndrome

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Tooth enamel due to its structure and the lack of remodelling processes allows, unlike other tissues of the body, to track developmental disorders occurring in the process of ontogenesis. The gradual process of enamel formation from the second trimester of pregnancy of primary teeth to a puberty (permanent teeth) allows the consolidation of metabolic traces that disrupt the functioning of ameloblasts during this period. Those developmental defects can be observed not only macroscopically, but also microscopically in the form of accentuated lines (AL). These accentuated lines appear during enamel secretion and differ from the correct, rhythmic Retzius lines in greater width and clarity.

The aim of the study is to compare the incidence of accentuated lines in children with Down syndrome (DS) and autism spectrum disorders (ASD) in relation to healthy children (HC) from the central Poland. The odontological material consisted of primary teeth (one tooth from one individual), without any developmental defects, caries, as well as were not subjected to any dental procedures. A total of 64 teeth were analyzed: 22 from ASD children; 8 from DS and 34 from HC. Statistical analysis showed a correlation between the children's health status and the AL number ($R= 0.489$). Healthy children had fewer AL compared to children with DS and ASD (respectively).

There are many publications analyzing the relationship between enamel structure and pre- and perinatal factors as well as the possibilities of using teeth to measure early-life biological stress. The presented study identified a higher frequency of accentuated lines in the enamel of primary teeth, which can be a sign of stress factors in first years of life or may indicate a greater sensitivity of children with analyzing disorders to environmental factors.

Dental Morphology and Morphometrics

O11

Acute or obtuse? Towards a universal classification of lophed cheek teeth

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A long-term goal of mammal palaeontology, reaching back to Cuvier if not beyond, has been to construct a universal, functional characterisation of the molars of plant eating mammals that would be applicable throughout the Cenozoic. Such a scheme would not only allow us to better understand and compare the function across different structures and shapes of cheek teeth but hopefully also to better quantify and model functional relationships between herbivore communities and their edible environments through their dental ecometrics. While good progress has been made with functional characterization of bunodont and lophodont molars, resolving the functional interpretation of the biomechanically more uniform but ecologically diverse selenodonts has been a long-standing challenge. To what extent can the compressed spectrum selenodont shapes be functionally mapped onto the broader morphological spectrum seen in lophodonts, from bilophodont to ectolophodont and plagiolophodont? Using a preliminary classification scheme applicable across all ungulate morphologies we ask what environmental characteristics we can predict solely from occlusal structures across living and fossil communities of large herbivores. We also present pilot results on how, according to the new scheme, the dietary composition of herbivore communities has varied throughout the Cenozoic. Our main purpose is to invite critique of the functional classification scheme that we propose.

Keywords: functional morphology, dental wear, biomechanics, ecometrics

O12

Possible phylogenetic influence on carnassial functionality as revealed by 3D geometric morphometrics

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Carnassial teeth with slicing function evolved convergently in multiple lineages of carnivorous mammals. A 3D geometric morphometric analysis of lower carnassials of extant Carnivora, Dasyuromorphia and extinct Hyaenodonta suggests besides functional adaptation a possible phylogenetic influence on carnassial shape. The shift between lesser and higher specialized carnassials in the PCA morphospace is described by an elongation of the carnassial blade, a reduction of the talonid basin and an increasingly asymmetric cervix line with an enlarged mesial and a reduced distal flexure; it explains the majority (41 %) of total shape variance. This shape shift is linked to the functional-morphological adaptation that evolved convergently. Additionally, a significant proportion of variance (14 %) is explained by the shape difference between highly specialized carnassials (as seen in most feliforms, all hyaenodonts and dasyuromorphs) and lesser specialized carnassials (as seen in certain feliforms and all caniforms). This difference in shape applies to a low carnassial shearing blade and a mesio-distally elongated crown base in all caniform and lesser specialized feliform carnassials. A reconstruction of the hypothetic ancestral state suggests that this is the plesiomorphic carnivoran condition. This condition makes it possible to combine a mesio-distally oriented and elongated carnassial blade with a fully functional talonid basin, as it is seen in foxes (*Vulpes* spp.). These carnassials are effective for slicing meat while remaining multifunctional, as food items can also be crushed. Hyaenodont and dasyuromorph taxa with lesser specialized teeth have multiple carnassials with a slightly compressed crown base and a transversally oriented cutting blade, performing a “sequential” cutting. This possibly is the ancestral condition for dasyuromorph and hyaenodont carnassials, implying a difference to the more efficient condition for meat slicing in ancestral carnivorans.

Keywords: geometric morphometrics; functional morphology; carnassials; Carnivora; Hyaenodonta

O13

Functional analysis of the dentition of *Lesmesodon* (Mammalia, Hyaenodonta)

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Due to preservation in occlusion in flattened specimens, the dentition of the proviverrine hyaenodont *Lesmesodon* from Messel is inadequately known, only from subadult individuals. New μ CT-based studies provide now details from lingual, buccal and occlusal aspects of its dentition. This will help to gather information on the ecological niche that *Lesmesodon* occupied in the Messel ecosystem and which nutritional range it had.

We analyzed the dental function of the Eocene genus *Lesmesodon* and its sister taxon *Proviverra* by reconstructing the wear facets and their respective chewing cycle with the Occlusal Fingerprint Analyzer software and compared them with those of three modern carnivoran taxa. For reconstruction of the different carnassial morphologies Avizo and Innovmetric Polyworks were used.

The teeth were compared by quantification of their contact areas (wear facets) and the calculation of the duration of the contact. Subsequently the masticatory path was reconstructed in detail. Even though the close relatives *Lesmesodon* and *Proviverra* shared morphologically similar dentitions they show some differences revealed by the OFA analysis. Wear facets of *Lesmesodon* revealed a primary function in shearing and crushing food while facets of *Proviverra* seemed to be more suited for cutting while still saving a fair amount of shearing function. Chewing cycles in the insectivorous species, however, show similarities in their respective chewing cycle in terms of duration and maximum intercuspatation, while species more specialized in either carnivory or omnivory show contrary trends, which can be clearly separated from the insectivores.

Our study showed that the small hyaenodont *Lesmesodon* apparently occupied an insectivorous- omnivorous dietary niche in the Messel ecosystem and how the dentition of the insectivorous species in this study differ despite their at first glance same adaptations.

O14

Morphological and morphometric comparison of the first lower molar in Pantherinae (Felidae, Mammalia)

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In Felidae the carnassials (fourth upper premolar and first lower molar) play a crucial role in their hypercarnivorous diet. Hence, these teeth should be particularly suitable for defining simple species-specific characters which can help identifying partial skeletons, e.g., fossils or seized animal remains. An additional distal cuspule below the protoconid of the first lower molar (m1) is traditionally used as one dental feature to distinguish *Panthera tigris* from *P. leo*. However, in literature there is no congruent pattern, which Pantherinae (i.e., *Panthera*, *Neofelis*) species display this cuspule, due to sample sizes and only cursorial descriptions of the cuspule. Furthermore, its homology is still debated.

Hence, we created the largest sample (n=1660) of Pantherinae skulls which includes all extant species for m1 analysis, to date. We scored the number and distinctness of the cuspules as (1) one cuspule, (2) one cuspule and one tiny cuspule, (3) two clearly detectable cuspules, (4) more than two cuspules. In addition, we measured the length and breadth of m1 and corrected body size by length of the mandible.

Our data suggests that the presence of these cuspules varies in Pantherinae species to different degrees. For instance, *P. leo* shows almost entirely score 1 whereas *P. tigris* covers all patterns although scores 2 and 3 dominate. There is a positive allometry of m1 size with mandible length. Corrected for body size larger species are separated from smaller ones with *P. onca* showing an intermediate size pattern. In absolute values, *Panthera* and *Neofelis* are separated. Sexual dimorphism is only present in m1 size in that female of all species are smaller. This is more apparent in the breadth than in the length.

Our study shows that a combination of both distal cuspule pattern and size of m1 can be used to significantly narrow down the options when identifying Pantherinae species, while different species can be distinguished from each other to different degrees. However, due to intraspecific variation residual uncertainty remains.

O15

Loph morphologies and diet in cercopithecids

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The cercopithecids are one of the most successful adaptive radiations among primates. They represent a large part of the order's taxonomic diversity and are widely distributed.

The extant Cercopithecidae inhabit varied environments and present diverse behaviors and diets. Yet, they all share a distinctive dental feature: bilophodonty. Lophs are hypothesized to represent dental features adapted to fragment leaf-like food and/or to guide occlusal movements.

In order to understand their function and how they relate to life history traits such as diet, we characterize their form using 2D geometric morphometrics in a sample of 20 cercopithecid genera, including 23 colobines and 19 cercopithecines representative of the family dietary range. Two datasets were acquired on 3D virtual models of second upper molars using respectively 3 or 5 landmarks and 22 or 32 semi-landmarks. The analysis was performed independently on mesial and distal lophs.

Based on literature, we considered 4 classical food categories covering the diet of our primate sample. We used these categories to define the principal and secondary diet of the species under consideration, in order to test the relationship between diet and loph morphology.

Our results show significant differences of lophs morphology for both primary and secondary diets. Colobines consuming mainly leaves have significantly higher lophs and distant cusps, whereas cercopithecines have deeper lophs and close cusps. After phylogenetic correction, our results do not show significant differences in loph forms between our selected cercopithecids diets.

Difference in loph morphology in extant cercopithecids seems highly related to their initial radiations, but functional adaptation yielding to lophs selection need to be better understood especially in terms of food consumption. Thus, studying fossil form of cercopithecids is crucial to understand the form-function relationship between lophs and diets, if any, over time.

Keywords: geometric morphometrics; dental occlusal patterns; primates; adaptation

O16

Exploring the dental toolkit of primates using dental topography and the doolkit package

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Dental topography is an array of methods that assimilate the biting surface of the tooth to a landscape. Most dental topography methods represent the tooth surface as a three-dimensional polygon mesh, which can be used to compute and map dental relief, but also basin shape or cusp sharpness. Four variables are used predominantly in dental topography: slope, relief indices, orientation patch count – an estimate of tooth complexity, and Dirichlet normal energy – an estimate of tooth sharpness. They correlate with ability to fragment different kinds of foods, making dental topography a promising method for the study of tooth form and function.

Still, there is a large number of less used topographic variables scattered in many different software. The package doolkit is an attempt to group these methods within the R environment while solving some issues with the existing packages. It centralizes 15 continuous variables and a little more than 30 topographic indices, including state-of-the-art methods.

In this work, we introduce some of these methods and test their ability to separate dental surfaces according to diet. The sample is composed of 215 upper and lower second molars from 37 genera, spanning across all extant primate families. After homogenizing polygon size and number, smoothing the meshes and orienting the surfaces, a complete dental topographic analysis was performed using doolkit. Afterwards, a multivariate analysis was performed, again within the R environment.

As expected, we found that insect-eating species significantly differ from seed-eating species. In contrast, fruit- and leaf-eating primates cannot be separated when used as broad categories. However, we found a great diversity of forms within fruit- and leaf-eating species. These differences can be explained by the material properties of the food when they are known, suggesting that 'fruit-eaters' and 'leaf-eaters' encompass a broad range of very different challenges from the tooth perspective.

O17

New approach to assess the relationship between macrowear and enamel thickness in lower first molars.

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Variation in enamel thickness has been identified in modern humans from different time periods and between tooth types and populations. However few studies have tried to describe the linkage between 3D enamel thickness and dental wear to observe whether an adaptive response to the environmental and cultural context happens at a population-level.

The present work aimed at investigating the relation between 3D Average Enamel Thickness (AET) and wear pattern of permanent lower first molars (wear stage 3) of specimens who lived between the Neolithic and the Bronze Age in Croatia by using a new 3D method based on two virtual knives cutting the enamel and coronal dentine in three parts to calculate 3D AET according to each masticatory phase. We analyzed individuals coming from the Neolithic site of Beli Manastir (n= 10), the Eneolithic site of Potočani (n=12), and the Bronze Age site of Bezdanjača (n=6), representing the heart of ancient migration routes through Europe as confirmed by the genetic contacts with communities' further north in the Carpathian Basin during the Bronze Age, contrary to the strong genetic continuity and local population interaction characterizing the Neolithic groups. Our results show that the 3D AET is higher in Bronze Age than in Eneolithic and Neolithic teeth. Specifically, we find significant differences in Buccal AET between the Bronze Age and the Neolithic providing a detailed resolution of enamel thickness distribution along with the dental crown. Macrowear patterns document a significant prevalence of Buccal wear among the Bronze Age individuals as opposed to higher values of Lingual wear in Eneolithic and Neolithic teeth. Finally, individuals belonging to the Bronze Age seem to be characterized by a buccal area that appears morphologically different (i.e expanded paraconid) to the other chronological groups. In conclusion, our results support the hypothesis of an adaptive response of dental tissues that could be attributed both to genetic contacts with non-local populations during the Bronze Age and change in dietary habits.

O18

The frequency of taurodontism in the historical population of Radom (11th-19th centuries).

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Taurodontism as a morphological anomaly of multi-rooted teeth, concerning both deciduous and permanent teeth, consists in apical displacement of the bottom of the tooth chamber and shortening of the roots.

The aim of the work is to analyze the frequency of taurodontism in individuals inhabited historical Radom from the early Middle Ages to modern periods.

The research was based on the analysis of X-ray images of 636 molars of individuals from the 11th/ 12th c. (n = 120), 14th/17th c. (n = 76) and 18th /19th c. (n = 444). Radiographs were made with the use of a portable X-ray machine. The obtained results of biometric analysis using the Shiffman and Chanannel index. Statistical analysis was performed with Pearson Chi-square test between historical periods and genders.

The significantly highest frequency of teeth with taurodontism was observed in the 18th/19th c. (31%, 138/444, p=0.006). In the 11th/12th c. and 14th/17th c. this percentage was significantly lower (22%, 26/120 vs. 16%, 12/76, p=0.006). In the 11th/12th c. and the 14th/17th c., more taurodonts were found in males than in females (p=0.188). In the modern period, the defect appeared at a similar level in individuals of both sexes. The greatest number of teeth with taurodontism was observed among the third and second upper molars (87%, 71%), and the least among the first and second lower molars (10%, 21%). In all historical periods, the highest number of hypotaurodonts, and the lowest number of hypertaurodonts forms were observed (p>0.05).

The highest frequency of taurodontism, observed in the 18th/19th c., may be related to the large migration of the population to the city. This fact was also diagnosed by genetic research. Modern epidemiological studies are consistent with both the type of teeth most often affected by taurodontism, and the form of its advancement.

Keywords: Taurodontism; Radom; dental material

O19

Dental metric on the Late Holocene to Current Era Population from the Lowland part of Indonesian-Papua

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In an attempt to understand human history in this world, the researchers have applied several methods to identify the group of populations based on the teeth trait characteristic. However, the lack of knowledge about human diversity from several regions in this world derived from the osteological study from archaeological context has limited the understanding of human history in many societies including the populations that occupied the lowland part of Indonesian-Papua. For this, the aim of this study is to reconstruct the population history by employing the dental metric measurement on the 304 samples from the archaeological sites in the lowland parts of Indonesian-Papua which are classified into two different groups, Late Holocene and Current Era. The multivariate statistics analysis was applied to compare the results from the Lowland Indonesian- Papua samples with 17 groups of the population included in this study. The results from the statistics measurement were further used to reconstruct and visualize the phylogenetic tree by employing The Neighbor-Joining method and UPGMA algorithm. The result from this clustering group presents the data about Austronesian inheritance in the group of Late Holocene and Current Era occupied the lowland part of Papua in the past. The comparison between the tooth variable of the two groups of the Lowland populations: the Late Holocene group and the Eighteenth Century shows several differences. The average tooth size distances in a few tooth variables from these two groups of Lowland populations suggest that they may have been carried different genetic material, in this case, Papuan and Austronesian speakers.

O20

The Evolutionary Changes in Molar's Root Morphology in Holocene Levantine Populations

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Tooth morphology is associated with the demands of occlusal loads, mechanical resistance and dietary adaptations. This association was assessed in studies of primates and other mammals revealing that measures of root surface area, root-to-crown-surface area or root splay are related to tooth mechanical resistance.

As roots are responsible for absorption and dissipation of occlusal forces, and designed to minimize tooth wear or fracture, exploring their morphology might reveal new insights regarding the function of the masticatory apparatus. Our hypothesis is that there was a reduction in molars' root size and robusticity during the Holocene as an adaptation to dietary changes and reduced masticatory demands.

The aim of the study was to characterize the evolutionary changes in molars' root morphology and to evaluate the relation to masticatory function.

The study sample included Levantine populations; 25 recent modern humans (e.g., Bedouins), 26 Natufians (15,100-12,000 Cal BP), 22 Neolithic (10,500-8,350 Cal BP), 30 Chalcolithic (6,500-5,500 Cal BP).

Mandibles containing first and second molars with full developed roots were scanned using Nikon μ C.T. system. Segmentation and 3D reconstruction of the scans were done using Amira software. 3D geometric morphometric analysis and linear measurements of roots (e.g., centroid size, root shape, furcation height, surface area, root length and cervical area) were done using EVAN Toolbox 1.71 and Rhinoceros 5 software. The morphological traits of the roots were evaluated in relation to proximal attrition facets that were used to evaluate the masticatory function.

Our results indicated a trend of reduction in the absolute size of the molar roots (cervical area, cervical width, root surface area) from Natufian to recent moderns ($p < 0.001$). Yet, the relative size indicating roots' proportions (root/cervical area) along with the proximal facet area did not change. Proximal facets size was associated with roots' size measurements (e.g., root area, furcation length, root/cervical area). This might indicate the adaptation of teeth roots to reduced occlusal demands while preserving optimum function. The physiological need to adapt to various dietary and functional changes during the Holocene, resulted in a dynamic evolutionary change in dental roots' morphology.

O21

Dental morphological indicators of Native Mexican Ancestry are associated with greater cranial fluctuating asymmetry in Colonial Mexico City.

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In Mexico City during the Colonial period (1521-1821 CE), the *Castas* system determined individuals' rank in society, including what neighborhood people could live in, what occupation they could have, and whether they could own land or a firearm. This system was based on each individual's specific parentage, with categories for many combinations of European, African, and Native Mexican ancestry. Here, we tested whether the *Castas* system had a direct effect on developmental stress for those who lived during this time. The sample derived from two colonial-period ossuaries in the heart of Mexico City, Soledad and Catedral (n=71). These were compared to ancestral samples of West Africans (n=281), Europeans and North Africans (n=226), and pre-contact Native Mexicans (n=460). Cranial fluctuating asymmetry (CFA) was used to indicate exposure to developmental stress. Linear discriminant analysis (LDA) estimated from dental morphological traits was used to estimate relative similarity to the three ancestral groups. Together, LD1 and LD2 explain 92.4% of the variation in dental morphology. These LDA results were then used in a linear regression to determine whether ancestry is associated with CFA. With increasing values of LD2 (y-axis; 33.7% variation), CFA decreases ($p=0.033$), indicating that individuals with dental morphology more similar to African or European ancestors have less CFA, while those with morphology more similar to Native Mexican ancestors have more CFA. This provides evidence that ancestry structured exposure to developmental stress in Colonial Mexico, a conclusion long suspected but never before directly tested.

O22

A 2D geometrical morphometric model of the lower third molar of the archaeological dwarf deer from Pedro Gonzalez Island (Panama)

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Cervid taxonomy from Central and South America, despite the work in the last years, is largely unknown. The *Mazama* genus includes species of small neotropical deer with simple horns, adapted for movement in environments of dense forests and closed vegetation. This genus is one of the more diverse genera among deer with ten recognized species, their classification is controversial because of their complex phylogenetic relationships. The genera *Mazama* represent separate radiation events with high levels of molecular and cytogenetic divergence being a polyphyletic genus. There is no consensus in the precise position of all *Mazama* species, the studies based on molecular data agree in pointing to a close relationship between two clades, the gray clade composed of *M. gouazoubira* and *M. nemorivaga*; and the red clade formed by *M. americana*, *M. temama*, *M. bororo*, *M. rufina*, *M. chunyi*, *M. bricenii*, *M. nana* and *M. pandora*. The archaeological site of Playa don Bernardo (PdB) is located on Pedro González island at Pearl Island Archipelago in Panama. This site was inhabited by humans between 6200-5600 cal yr BP. They were farmers who cultivated maize and root crops. When they reached the island, they found a local dwarf deer (< 7 kg) population. The archaeological record shows evidence that dwarfed deer were the most abundant terrestrial mammal in the assemblage. Deer remains decreased across time, with none remaining at the end of the human occupation. The taxonomic identification of the dwarf deer is not clear. The aim of this presentation is to explore the taxonomy of this dwarf deer through the use of geometric morphometrics by comparing the lower third molar of the archaeological samples with extant *M. americana*, *M. temama*, *M. nemorivaga*, *M. gouazoubira*, *M. bricenii*, *M. nana* and *Odocoileus virginianus* from museum collections. The results suggest that the species of deer that inhabited PdB was related to the red clade. It is possible that PdB deer were the dwarf form of the red clade.

Keywords: neotropical cervids; Preceramic; *Odocoileus virginianus*; *Mazama* sp.; taxonomy

O23

Comparing Biodistance Estimates from Deciduous and Permanent Dental Morphology in a Sample from the Pre-Hispanic Southwest United States

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Biological distance (biodistance) analysis is a key method used by bioarchaeologists to examine population structure in the past. Often, such analyses are done using nonmetric traits of the permanent dentition as representations of underlying genetic variation. Rarely do researchers utilize the deciduous dentition when examining biodistance in archaeological assemblages. Here, we compared the results of biodistance analyses using permanent and deciduous dental morphological traits from the skeletal remains of individuals in the pre-Hispanic Southwest United States. The sample consists of 100 individuals with deciduous teeth and 325 individuals with permanent teeth. We observed 20 traits in the deciduous dentition and 56 traits in the permanent dentition. Deciduous traits were scored following Hanihara's and Sciulli's descriptions. Permanent teeth were scored using the ASU Dental Anthropology System, as modified by Edgar. Observations were first dichotomized, then traits were compared using tetrachoric correlation. After eliminating correlated traits, we performed mean measure of divergence (MMD) to estimate biodistance as reflected in the permanent and deciduous dentitions. We compared the distance matrices using a Mantel test, which was not significant ($R = 0.25$, $p = 0.16$). This contradicts previous research which has shown significantly strong correlation between distance analyses using permanent and deciduous teeth. While our results support a similar pattern of relationships in the population structure, the use of deciduous dentitions in biological distance analyses may reveal additional trends that are hidden when only studying permanent teeth. Indeed, recent research indicates that deciduous morphological traits are likely a better reflection of underlying genetic variation since they are less impacted by environmental stress. Further, we suggest researchers consider both the deciduous and permanent dentitions when using biodistance in order to more fully understand population structure.

O24

Solving the *Hemanthropus peii* mystery

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The hominid taxon "*Hemanthropus peii*" was erected by von Koenigswald in 1957 based on a set of isolated teeth collected from Chinese drugstores, with the upper molar CA 673 set as the holotype. The exact origin and context of these specimens is unclear, except that they come from southern China. The species has been originally attributed to the Homininae clade, and further studies tentatively regarded it as an australopithecine or as a member of *Homo*. A recent revision of the "*H. peii*" dental assemblage, including CA 673, concluded that it most likely represents fossil orangutans based on two-dimensional analyses of the enamel-dentine junction (EDJ) and tooth development. However, the bunodont and high-crown morphology of CA 673 markedly differs from the usual morphology of extinct and extant *Pongo*, indicating that the taxonomic attribution of this tooth might be unresolved. In addition, CA 673 has been described as an upper permanent second or third molar, but the large hypocone and overall shape suggest that it might represent either a maxillary deciduous molar or a first permanent molar. Based on X-ray microtomographic scans, we characterized the endostructural organization of CA 673 and we conducted 3D geometric morphometric analyses of the EDJ, comparing the holotype of "*H. peii*" samples of upper deciduous and permanent molars of fossil and extant hominids. Our results unambiguously exclude that CA 673 belongs to *Pongo* and demonstrate that it shares marked affinities with Neanderthal deciduous and permanent molars. However, the larger crown size and peculiar EDJ shape, together with a number of non-metric features resemble those of the molars Denisova 4 and Denisova 8. In addition, the long-period periodicity of enamel (9–11 days) estimated in CA 673 is comparable to that measured in Xujiayao 1, suggested to belong to a young Denisovan individual. Altogether, our results indicate that CA 673 might represent a Denisovan, which implies that due to the taxonomic principle of priority, *Homo peii* would be the formal name of the species.

Dental Life History and Ecology

O25

Comparison of crown growth parameters in molars of *Hippopotamus minor* and *H. amphibius* based on incremental markings in enamel

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The fossil pygmy hippo of Cyprus (*H. minor*) is the smallest of all known hippo species with a body mass of less than 10% of its mainland ancestor. Insular dwarfing has occurred in various large mammal lineages and it is debated whether it involves a slowing down or a speeding up of life history. To contribute to this discussion, we reconstructed crown growth parameters in molars of *H. minor* and *H. amphibius* based on the analysis of incremental markings in enamel. Crown height of the *H. amphibius* M³ was about 3.4 (M³) or 4.0 times (M¹) higher than molar crown heights in *H. minor*. Maximum linear enamel thickness was also markedly higher in the *H. amphibius* M³ (~ 3.400 µm) compared to the M³ (~1.900 µm) and M¹ (~ 1.400 µm) of *H. minor*. Crown formation time (CFT) of the *H. amphibius* M³ was 1882 days, compared to, respectively 501 and 356 days for M³ and M¹ of *H. minor*. In contrast, daily enamel secretion rates (DSRs) were similar (mean values of 10 – 11 µm/day; range 5 – 14 µm) in both species. Higher enamel thickness in *H. amphibius* is achieved by an extended duration of secretory ameloblast activity (maximum secretory lifespan of 420 days in the M³) compared to *H. minor* (210 days in the M³ and 152 days in the M¹). Enamel extension rates (EERs) of *H. amphibius* and *H. minor* molars were similar (highest values of 73-80 µm/day in cuspal enamel; lowest values of 11-13 µm/day in the M³s and of ~25 µm/day in the M¹ in cervical enamel). The long-period (Retzius) repeat interval was higher in *H. amphibius* (11 days) than in *H. minor* (5 days). Our results indicate that the reductions of molar size and enamel thickness in the course of the dwarfing process are attributable to a truncation of CFT. This involves a shortening of secretory ameloblast lifespan and a decrease of the Retzius repeat interval. However, ameloblast secretory (DSR) and differentiation (EER) rates were largely unaffected. Thus, the dwarfing process in *Hippopotamus* was associated with alteration of the infradian rhythm of amelogenesis while the circadian secretory activity remained largely unchanged.

Keywords: crown formation time; daily secretion rate; enamel extension rate; insular dwarfing

O26

Trace element profiles in enamel from histologically-controlled laser-based mass spectrometry reveal dietary cyclicity in *Pongo* and *Homo erectus* from Sangiran

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The hominid fossil record from the Sangiran Dome in Java is among the largest in Southeast Asia and provide evidence of an early dispersal of *Homo erectus* onto the Sunda Shelf during the Early Pleistocene. The high morphological variability in the fossil record has been linked to an increased diversity in hominid taxa on Java during the Pleistocene. The seasonal availability of food resources, combined most likely with phases of connections between landmasses, and niche partitioning within hominids, may have contributed to this biodiversity. We performed the first geochemical analyses on fossil enamel of *Homo erectus*, *Pongo* and associated large mammal fauna from the Sangiran Dome to infer dietary strategies at ~weekly time resolution. Trace element ratios (Sr/Ca and Ba/Ca) were obtained by utilizing histologically-controlled spatially-resolved laser-ablation inductively-coupled-plasma mass spectrometry (LA-ICPMS) analyses. The degree of post-mortem diagenetic modification of the biogenic Sr/Ca and Ba/Ca signals was assessed using trace elements such as U and Mn. In addition, stable carbon and oxygen analyses ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$) were performed on one *Homo erectus* premolar to estimate palaeoclimate and contribute to dietary assessments. Sr/Ca ratios of mammalian teeth with known trophic positions provide a trophic level framework for the hominid specimens. *Pongo* displays an herbivorous signal, whereas Sr/Ca ratios of *Homo erectus* are in range of omnivorous and carnivorous mammals. *Pongo* and

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Homo erectus exhibit annual patterns in their time-resolved Sr/Ca profiles. The distribution pattern of Sr/Ca (and Ba/Ca) along the enamel dentine junction in *Pongo* shows distinct seasonal cycles, with high and narrow peaks indicating the consumption of peculiar plant-based food resources probably during monsoon seasons, and low values reflecting different food availability during dry seasons. *Homo erectus* enamel has a relatively low annual Sr/Ca intra-tooth variability, suggesting that it was able to meet its nutritional needs more independently of seasonal oscillations.

O27

Effects of Vitamin D deficiency on tooth mineral density and chemical composition

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Severe Vitamin D deficiency can result in developmental defects in bone and tooth mineralisation. However, effects of milder levels of vitamin D deficiency on tooth mineralisation are still unclear. We analysed tooth mineral density using Micro-CT, and chemical composition via Energy Dispersive X-ray analysis (EDX) and Raman Spectroscopy, in the enamel and dentine of primary exfoliated lower incisors in 64 5-6 years old children, mostly of NZ European ancestry. Cord blood levels of Vitamin D were used to define levels of deficiency, insufficiency, or sufficiency (Deficient <30 nmol/L; Insufficient 30-50 nmol/L; Sufficient >50 nmol/L). Mineral density values ranged from 1.41 g/cm³ in inner dentine to 2.46 g/cm³ in enamel, and total density ranged from 1.74 g/cm³ in inner dentine to 3.24 g/cm³ in enamel. There were no significant differences in mineral density and total effective density among deficient, insufficient, or sufficient samples, both in enamel and outer and inner dentine. Calcium oxide weight percentages ranged from 51.4% in inner dentine to 53.8% in enamel. Phosphorous oxide weight percentages ranged from 43.9% in outer dentine to 44.4% in enamel. Calcium and phosphorous oxide weight percentages were also similar among the Vitamin D groups in enamel and inner and outer dentine. Raman Spectroscopy analysis showed that participants with sufficient levels of Vitamin D exhibited higher structural order (more crystallinity) in enamel than deficient and insufficient groups. With exception of higher crystallinity in enamel detected via Raman Spectroscopy, we did not observe major changes in mineralization and chemical composition among participants with deficient, insufficient, or sufficient Vitamin D levels. Future research should investigate other teeth prone to developmental anomalies of enamel and dental caries, particularly the primary molars which calcify around the same time as incisors.

Keywords: enamel; dentine; EDX; Micro-CT; Raman Spectroscopy

O28

Dietary Reconstruction of Levantine Holocene Populations based on Dental Microwear texture

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The transition from a subsistence-based food gathering and hunting society to a food-producing society is one of the most significant cultural processes in human history. This process in the Levant (14,900 cal BP- 8,250 cal BP) is distinguished by large-scale changes in lifestyle, including diet, culture, and habits. Some of these changes can be reflected by investigating dental remains, particularly dietary habits, which can be investigated using dental microwear texture analysis (DMTA). The current study aimed to explore dietary habits in Levantine prehistoric populations using DMTA.

Material and Methods:

The study sample included 52 specimens representing the Holocene Levantine populations: 14 Natufian (14,900–12,000 cal BP), 19 Neolithic (12,175–8250 cal BP), 12 Chalcolithic (6500–5500 cal BP) and the 7 Recent Modern individuals (Bedouins).

Second Molar teeth with occlusal wear facets were examined by a high-resolution confocal disc-scanning measuring system (NanoFocus AG). 3D surface models were analyzed using two different methods:

Scale-Sensitive Fractal Analysis (SSFA) – using SFrax and Toothfrax software. Two parameters were used to describe a wear surface: complexity and anisotropy.

3D areal surface texture standards (ISO 25178–2) – using μ soft analysis premium v.5.0 software. Includes 30 roughness parameters for surface texture.

Results:

Based on the SSFA analysis, the complexity results show significant differences between Natufian and Chalcolithic (sig. < 0.001), indicating a greater frequency of pits and deeper scratches in the Chalcolithic, suggesting consumption of abrasive food that can be related to more advanced processing methods. Significant differences in the anisotropy measures were found between Natufian and Chalcolithic (sig. = 0.002) and between Natufian and recent modern (sig. = 0.006). This indicates the consumption of a tough and fibrous diet by the Natufian, which characterizes unprocessed and raw food. The ISO results, revealed a significant difference in wear patterns between the three prehistoric samples, allowing us to characterize a distinctive microwear pattern for each of the populations. Revealing the unique microwear features of each population may provide better understanding for dietary habits and food processing techniques.

O29

Problematic breastfeeding practices in two post-medieval finnish towns according to $\Delta^{15}\text{N}$ and $\Delta^{13}\text{C}$ analyses of archaeological dentin

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In mid-18th-century Sweden, the newly enhanced census records revealed higher-than-expected infant mortality rates in certain regions of the Kingdom. This convinced many contemporary men of the elite of common women deliberately refusing to breastfeed out of vanity and carelessness. One of the worst regions in terms of infant mortality was the province of Ostrobothnia located in the area of nation of Finland (during the observation period, first part of Sweden and later Russia). There artificial feeding using milk horns was said to be common, while in southwestern parts of the country breastfeeding was often traditionally preferred. I have explored whether such a regional division is traceable in the remains of the contemporaneous people. I compared the results of the $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ analyses of collagen of horizontally cut 1 mm dentin segments of permanent first molars (M1) of 13 individuals which we have previously obtained to address the breastfeeding practices. Their remains were excavated from the local churchyards of the late 17th- to early 18th-century town of Oulu, Ostrobothnia (n=6), and the late 18th- to early 19th-century town of Rauma, Southwestern Finland (n=7). In Rauma, the resulting isotopic profiles were similarly patterned across the sample indicating quite long periods of breastfeeding. In Oulu, however, the breastfeeding practices may have been more versatile. All infants were not necessarily breastfed in a sufficient way. However, instead of accusing contemporary mothers of deliberate neglect, this may be explained by the general hardships of their everyday lives.

Keywords: stable isotope analyses; dentin; post-medieval period; Finland; breastfeeding

O30

Determination of Dental Age and Diet in the Illyrian Population from the Kopila necropolis on the Island of Korčula, Croatia

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This paper presents the changes caused by macroabrasion of teeth on skeletal remains found in tomb No 4 in the west necropolis of the archeological site Kopila near Blato on the island of Korčula. The site archeologically dates back to the Late Iron Age, when the island was inhabited by the Illyrians.

Purpose: The aim of this study was to assess the dental age of the buried individuals at death and determine the type of their diet, which could give us a preliminary insight into the socio-economic standard of the inhabitants of the settlement.

Material and methods: The analyzed sample is a part of the collection of excavated skeletal remains kept in the Vela Luka Cultural Center on the island of Korčula. 284 permanent teeth, 19 fragments of the maxilla and 20 fragments of the mandible were found in the tomb, which were classified into 32 individuals and by sex. Teeth were analyzed by metric and non-metric methods of determining dental status in order to assess the dental age at the time of death and the diet of the inhabitants. The dental age of individuals was determined by the Lovejoy method and the degree of tooth wear by the Smith-Knight method. The analysis of the stable isotope ^{14}C determined the exact time of death of the analyzed individuals.

Results: The abrasive changes were very pronounced and present on 92.9% of teeth, equally on incisors and molars ($p = 0.236$). There is no significant gender difference ($p > 0.05$ for all teeth and jaw parts). There was no difference in the degree of abrasion of the teeth of the mandible and maxilla ($t = -0.266$, $p = 0.791$), nor in the degree of abrasion of the teeth of the maxilla right and left ($t = -0.392$, $p = 0.702$) or in the degree of abrasion of the teeth of the mandible right and left ($t = -0.889$, $p = 0.390$). The average age of the analyzed population sample was 35.6 (+/- 3.1) years. They were buried between 360-40 BC.

Conclusion: Abrasive changes observed on the analyzed teeth indicate a diet rich in hard, abrasive, weakly cariogenic food with particles that were probably of inorganic origin, which caused an increased wear of tooth structures. The population was sedentary, agricultural type and the life expectancy was normal for the Late Iron Age. Besides, their socio-economic status was good. The age at the time of their death was between 30 and 40 years.

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Keywords: teeth; dental age; dental wear; Illyrians; Late Iron Age

Dental Biomechanics and Evolutionary Dentistry

O31

The triconodont molar form and function

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The triconodont molar pattern is characterized by three linearly aligned main cusps and characterises non-mammalian Mammaliaformes such as Morganucodonta. While most mammaliaforms subsequently evolved more complex molar patterns by angulation of main cusps and addition of new cusps, one group of early crown mammals, the Eutriconodonta, retained the triconodont molar pattern with certain modifications. We have analyzed morganucodontan and eutriconodontan triconodont molars and reconstructed their occlusal pattern with the Occlusal Fingerprint Analyser (OFA) software and found fundamental differences in function and inferred diet. The plesiomorphic triconodont molars of insectivorous mammaliaforms (morganucodontans) centered around shearing with an additional emphasis on puncturing with their massive central cusps. Two different modes of occlusion existed among Morganucodonta; embrasure occlusion (the central cusps occlude between two antagonists) and *Morganucodon*-like occlusion (the upper central cusp occludes between two cusps of the same lower antagonist). The difference was determined by molar positioning and the spacing between individual cusps. The more derived eutriconodontan molar is characterized by a high degree of uniformity and precision, and uniquely combined properties seen in insectivorous and carnivorous modern-day mammals. While this precision and uniformity ensured good cutting capabilities, it presumably put the dentition under greater evolutionary constraints than other molar types with more heterogeneous cusp morphologies. This explains the highly stereotypical nature of many eutriconodontan molars, as well as the development of unusual molar eruption patterns in the ascending ramus. Many “triconodont” taxa also show lingually inclined upper molars, which is interpreted as a mechanism to reduce the amount of roll required to keep the teeth in contact during occlusion.

O32

Jaw mechanics in shrews and the role of the double articulation

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The efficient fragmentation of food, essential for sustaining a high metabolic rate, is determined by the molar morphology and the movement of the jaw which is in turn related to the jaw morphology and the arrangement of the masticatory muscles. Already in early Mammaliaformes such as *Morganucodon oehleri* the typical mammalian arrangement of the three masticatory muscles (temporalis, masseter, pterygoid) and their subdivision into two parts were present. The evolution of the angular process on the mandible which provides the insertion area for the pterygoid and the masseter is, depending on the author, either linked to an increasingly yaw (rotation around vertical axis) dominated chewing stroke or to an enhanced roll movement (rotation around longitudinal axis). Besides the development of a strongly posteriorly elongated angular process, the mandible of shrews shows a unique condylar process which is characterized by a separation of the articulation facet into a dorsal and a ventral part. This double articulation is thought to allow a more differentiated movement of the jaw. With the observation of tooth wear, 3D-reconstructions of the chewing paths, and the usage of the diceCT method, a non-destructive technique for visualizing soft tissue, we are able to show that the double articulation enables a combination of yaw and roll rotation which is governed by the two muscles inserting on the angular process. In conjunction with the contraction of the temporalis, mainly responsible for the pitch motion (rotation around transverse axis), the lower jaw gets rolled into occlusion (Phase I). During Phase II, when the protocone is grinding through the talonid, the internal pterygoid and the masseter produce an alternation of inversion and eversion of the mandible. These movements lead to an increased fragmentation of food due to the induction of a twist motion to the bolus in Phase I and a more varied grinding, caused by additional movement directions of the protocone, in Phase II. This allows for a more efficient energy gain and the maintenance of a high metabolic rate.

Keywords: Soricidae; masticatory muscles; jaw movements; temporomandibular joint; double articulation; dental function; occlusion; mastication; mandibular rotation; diceCT; diffusible iodine-based contrast-enhanced computed tomography; X-ray micro-CT scanning; 3D reconstruction

O33

Dental microwear texture analysis of rats receiving near-natural diets shows that seeds and insect exoskeletons cause high enamel surface complexity

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Complex dental microwear textures (DMT) representing differently sized and shaped enamel lesions overlaying each other have traditionally been associated with the seeds and kernels in frugivorous diets. Food items like seeds, nuts as well as sclerotized insect cuticles were often considered as causes of deep pit-like damages resulting in complex enamel surface textures in primate and hominoids. Recently, this notion has been challenged by field observations as well in-vitro experimental data. It remains unclear to what extent each food item contributes to the complexity level and is reflected by the surface texture of the respective tooth position along the molar tooth row. To clarify the potential of seeds and other potentially abrasive dietary items to cause complex microwear textures, we conducted a controlled feeding experiment with rats. Six individuals each received either a vegetable mix, a fruit mix, a seed mix, whole crickets, whole black soldier fly larvae, or whole daychicks. These diets were subjected to material testing to obtain mechanical properties, such as Young's modulus, yield strength, and a food hardness test (TPA). We found seeds and crickets to cause highest surface complexity. The fruit mix, seed mix, and crickets caused deepest wear features. Moreover, several diets resulted in an increasing wear gradient from the first to the second molar, indicating that increasing bite force along the tooth row leads to increasing dental wear in rats on these diets. Mechanical properties of the diets showed different correlations with DMT obtained for the first and second molar, with first molar wear being correlated stronger to maximum values observed for mechanical properties, while second molar wear was more correlated to mean mechanical properties. This indicates a complex relationship between chewing mechanics, observed DMT and food mechanical properties. Our results show that in a small mammal model organism, seeds are a main cause of complex microwear textures, but that also hard insect exoskeletons can cause complex microwear textures.

O34

The effect of force directionality and magnitude on dental enamel wear

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The enamel structure is prismatic and is consisted of rods oriented unevenly along the crown. This unique structure provides strength, hardness, and also contributes to the enamel's anisotropic qualities. In the current study, we aimed to explore how directionality of force affects enamel wear patterns.

Thirty-two human teeth were set in a custom-made dental attritional device and subjected to force applied in four different directions, using two magnitudes (2 and 4 newtons). The enamel crown was situated to allow four directions of force application: occluso-cervical direction (OC), cervico-occlusal direction (CO) Mesio-Distal (MD) and Disto-Mesial Direction (DM).

The resultant wear scars were measured using a high-resolution confocal disc scanning measuring system (Nanofocus AG) through surface profiles analysis. Calculation of enamel surface loss material revealed that in both the low and high force groups, the highest wear was produced by the OC direction (817.8 μm^2 and 10051 μm^2 accordingly, $p < 0.05$) and the lowest in the CO direction (177.1 μm^2 and 821.7 μm^2 , $p < 0.05$). While the horizontal force directions (MD, DM) were in the range between the OC and CO for both magnitudes. The OC direction differed significantly from all other three directions in both force groups ($p = 0.003$), implying the anisotropic behavior of the enamel.

When investigating enamel attrition patterns for bioarcheological reconstruction, one should take into account that the direction of force, as well as its magnitude, may influence the amount of wear. Furthermore, this finding should be considered in relation to clinical procedures that involve the grinding or polishing of enamel using dental tools.

O35

The Morphology of Non-Carious Cervical Lesions: What Can It Teach Us?

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Modern societies have experienced a remarkable increase in the occurrence of dental pathologies during the last century. Non-Carious Cervical Lesion (NCCL) is one of these "modern" pathologies, defined as the loss of cervical tooth material of non-bacterial etiology. Although cervical lesions are common (46.7%), the exact pathophysiology is unknown.

Cervical lesions are described in various forms that are probably related to their original etiology, with the most prevalent morphologies being wedge-shaped or saucer-shaped. This research aims to describe the shapes and surface textures of lesions so that NCCL pathophysiology can be better understood.

Eleven extracted human teeth with NCCLs were examined: five of the wedge-shaped type and six of the saucer-shaped type. Teeth were scanned using a Nikon Micro-CT system (17.2 μm voxel size). The volume and surface area of the lesions were measured. We also examined the texture of the lesions with a high-resolution confocal disc scanning system (NanoFocus AG).

Results indicated that the volume was larger in the wedge-shaped lesion ($p = 0.012$). However, the ratio of surface area to volume was larger for saucer-shaped lesions ($p = 0.003$). The results showed that the surface texture pattern of the wedge-shaped lesion was less homogenous than the pattern of the saucer-shaped lesion.

The wedge-shaped lesions have a bigger volume and a smaller surface area than the saucer-shaped lesions, which exhibit the opposite pattern. It should be noted that wedge-shaped lesions might spread toward the tooth pulp, causing structural damage and hypersensitivity, unlike the saucer-shaped lesions, which spread superficially and are less detrimental.

The homogeneous surface texture of the saucer-shaped lesion might indicate that erosive conditions are likely to be involved in its formation. In contrast, the variable surface texture of wedge-shaped lesions is more influenced by mechanical and abrasive effects.

O36

Facial asymmetry and chewing sides in twins

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The objectives of this study were to resolve how the preferred chewing side (PCS) affects facial asymmetry in twins, whether there are differences between monozygotic (MZ) and dizygotic (DZ) twins, and whether the twins with PCS have more asymmetric faces compared to symmetrically chewing twins.

The study included 106 Lithuanian twin pairs of the same sex, 59 MZ pairs and 47 DZ pairs. The faces of the twins were recorded by a 3dMDFace system (3dMD, Atlanta) based on stereophotogrammetry technology. The chewing side preference was first studied by asking. If the subject was not able to give an answer, they were asked to chew gum and their chewing was followed visually for a minute by the researcher. If the result was unclear, the test was repeated. If the result did not become clear even then, it was recorded that the subject used both sides for chewing.

We also developed a new method for measuring chin asymmetry from the facial 3D model, called Chin Volume Asymmetry Score (CVAS). The data was analyzed from facial 3D images and manually added landmarks. 3D images were analyzed by Rapidform2006 software and statistical analyses were done by using the R software environment version 4.1.0. Effect of chewing side preference on larger chin side was explored by using generalized linear mixed model with logit link function. Facial asymmetry between symmetrical and asymmetrical chewers was compared with linear mixed model. Possible genetic effect on PCS and facial asymmetry was examined by comparing pairwise tetrachoric and intraclass correlations between MZ and DZ twins.

The results showed that the contralateral effect of PCS and larger chin side was dominant among right and non-right side chewing twins. Being female increased the whole face symmetry. As a conclusion, the volume of the chin becomes larger on the side opposite to the twins' habitual chewing side. As the results are quite similar in both twin types, functional factors are more prominent than heredity. Supported by EOS grant.

O37

Quo vadis wear and 3D surface texture - bridging applications in paleoanthropology, archeology, biology and dentistry

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Dental wear has been widely investigated in paleobiology and paleoanthropology to infer diet, habitat and climatic conditions. During the last 10 years, the field of dental wear analysis was evolving on all scales. Combined studies based on museum material, in vivo, and in vitro experiments have shed new light on the importance of abrasives in the wear process, but also raised new questions. Here, I present a synthesis on the recent debate and advances to characterize the old as well as new important key players of the wear process in more detail. I introduce some new ways of thinking the wear process to test the connection between these key players and their interplay. Some of the advances were connected to tribological approaches that became more and more used during the last years. However, these approaches often left the user alone with cumbersome parameters and complex technological settings. In addition, here is still a need for standardization, to increase repeatability and reproducibility to guarantee high data quality and foster future exchange of data. To overcome these difficulties, I will discuss the most common pitfalls and present new tools and solutions that can help end users in various scientific disciplines. It will open up new research avenues to obtain a better understanding of the biomechanics and scaling of the complex and multi-factor interactions taking place during comminution.

O38

Craniomandibular dysfunctions as consequence of civilization

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Dental malocclusions are abundant in modern societies while they were rare and less expressed in pre-industrial times. Consumption of soft and refined food has been experimentally associated with small jaws, narrow dental arches and deep palate, high prevalence of dental crowding and impaction, and decreased total occluding areas.

There is no proof that malocclusion decreases fitness, and it is a fact that even severe malocclusion does not affect survival. Still, malocclusion is associated with several modern ailments, including respiratory problems, speech disorders, non-carious cervical lesions and periodontal diseases. However, the association to craniomandibular dysfunctions is controversial in dentistry.

To evaluate the effect of malocclusion on the health of the stomatognathic system, we conducted a systematic review and meta-analysis of the articles published between 1970 and 2021, testing the association between various types of malocclusion and clinically diagnosed temporomandibular disorders (TMD). We designed a new approach for the categorization and standardization of the occlusal determinants, including both static and dynamic features, and grouped dysfunctions based on the Research Diagnostic Criteria for TMD (1994).

Eventually, we analyzed 64 articles meeting our inclusion criteria. Results were synthesized by DerSimonian-Laird random effect models and presented as forest plots. We found significant associations between TMD and malocclusion, such as vertical and sagittal alterations from dental and skeletal class I, lack of posterior support, and alterations of lower jaw dynamic pattern. Heterogeneity of results was detected, likely due to differences in patient characteristics and applied methods.

Our outcomes showed that malocclusion, a by-product of our cultural and technological development, is associated with craniomandibular dysfunctions, which might be thus considered diseases of civilization. Hence, a deeper understanding of the effects of malocclusion on jaw kinematics is fundamental to inform dentistry in TMD patients' care.

O39

Modeling the histogenetic switch from enameloid to enamel

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Enamel and enameloid are hypermineralized tissues that can be found on the surface of vertebrates' teeth and odontodes. Contrary to enamel, whose origin is exclusively epithelial, enameloid is characterized by a dual epithelial and mesenchymal origin. The earliest evidence of enamel are found in stem-osteichthyans from the Silurian, while enameloid was already present in some stem-gnathostomes of the Ordovician. It has been suggested that enamel derived from enameloid, but it is still unclear what developmental processes would have had to be modified to induce this transition. It has been hypothesized that a delayed epithelial cell activity, a prolonged epithelial cell activity or a modification of the epithelial cells' production (from mostly collagen to mostly enamel proteins) could explain this transition. We built a cell-based histogenetic model based on simplified properties common to all current vertebrates. Depending on the parameters coding for the rules governing the behaviour of the secreting cells, the simulations are able to reproduce a large array of variation in terms of relative amount of dentine, enameloid and enamel. This allows us to explore the putative role of various developmental parameters in the enameloid to enamel transition. Our preliminary results suggest that this transition requires either the modification of the timing of initiation of vesicles' secretion or that of more than one developmental parameter, and that none of the three aforementioned hypotheses is sufficient per se to enable an enameloid to enamel transition.

Keywords: biomodelisation; EmbryoMaker; evolution; mineralized skeleton; vertebrates

Dental Forensics

O40

Automated personal identification based on tooth enamel microstructure

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Identification of cadavers is a global and overlooked issue. Only in the United States, the number of unidentified decedents annually is estimated to be around 1,000 cases. Part of the problem is linked to extensively degraded (e.g. burned) or skeletonized (e.g. only bones and teeth are present) remains, where only anthropological methods can be performed. Considering the dental remains, we have shown in previous works that an optical phenomenon on tooth enamel surface called Hunter-Schreger Bands (HSB) seems to be particularly distinct for each tooth and might be used as a biometric characteristic for personal identification. Also, tooth enamel can withstand high temperatures, wearing and aggressive environments, being found virtually intact in disasters as well. The aim of the current work is to develop a protocol for HSB usage as a new potential identification method, which we called "toothprint". Current results from a limited sample (31 extracted teeth, 4 images each) showed an average Equal Error Rate (EER) of 0.042. The process depends on a high resolution initial photography taken with macro lens, while the target tooth is lit sideways. From this photograph, HSB are enhanced, segmented from the background, filtered to remove noise, and transformed into a binary image representation. As of this representation, features are extracted and stored, or used for biometric comparison against other "toothprints". The process follows the same guidelines also applied for fingerprints, where ante-mortem data is required, albeit specific image processing techniques had to be standardized and are still currently in improvement. Next phases of the project involve validation on large datasets and in-mouth teeth. In addition, engineering for initial photography acquisition standardization will be required for large scale usage, as well as specific methods for data compression and storage. In summary, "toothprint" is a promising biometric methodology to help on human identification especially in cases of extremely degraded remains.

Keywords: Hunter-Schreger Bands; biometric identification; dental forensics

O42

Color Change in Teeth Due to Burning: Spectrophotometric Measurement

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Teeth are one of the most common skeletal elements for forensic identification purposes and also the strongest human tissue, making them resistant to high temperatures. Over the course of burning as temperature increases, teeth go through a process of structural change characterized by a carbonization phase (at approx. 400°C) and calcination phase (at approx. 700°C).

58 human teeth were burned for 60 minutes at either 400°C or 700°C. The change in color was measured quantifiably using a spectrophotometer to determine lightness (L^*), green-red color (a^*), and blue-yellow color (b^*) in order evaluate tooth color within the spectrum of human perception.

There is a significant difference between the L^* , a^* , and b^* of pre-burned teeth and 400°C ($p < 0.001$) and between 400°C and 700°C ($p < 0.001$). In addition, a difference in b^* value was found between pre-burned teeth and 700°C ($p < 0.001$). The mean $L^*a^*b^*$ values were used to calculate a measure of the perceptible difference between colors (ΔE) revealing a highly perceptible color difference between all temperatures (pre-burned, 400°C, 700°C).

During the carbonization phase the tooth gets darker and redder and as temperature increases, teeth become bluer. Overall, as calcination occurs the tooth root color gets closer to a neutral gray palette. The spectrophotometer allows an accurate measure of tooth color across various stages of the burning process. However, as the results showed a highly perceptible difference, for forensic purposes simple visual color evaluation can provide reliable information.

O43

Pathogenesis and Lines of Salter: insights into the biology of dental cementum for forensic applications.

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Cementochronology (also known as Tooth Cementum Annulation or TCA) is a technique that relies on the incremental growth of the dental cementum (*i.e.* lines of Salter) to estimate age and season at death. It has been widely applied as a black box technique for wildlife management, archaeology, and only occasionally forensic cases. Limitations include lack of clinical knowledge and of standardized protocols, limited samples availability and time-consuming procedures. As in the majority of cases the only samples available for research are pathological, this study investigates the effects of dental diseases, lifestyle and conditions more specifically related to the metabolism of calcium, on the microstructure, growth and reliability of the estimates from the cementum. The main purpose of this research was that of gaining some more insights on the inner mechanism of this tissue by analysing what it is affected by and how. Preliminary results show that, on pathological teeth, age at death can still be estimated within a margin error of ca. 10 years (which is still to be considered a remarkable achievement in age estimation of adult individuals). Recurring trends also show that the cementum thickness is significantly thinner in people affected by kidney stones, chronic kidney disease, osteoporosis, hypothyroidism and arthrosis; whereas its microstructure (*i.e.* the lines of Salter) appears altered or not visible in individuals that smoke regularly. Future studies will not only investigate whether these findings might give a hint on the biological causes and rhythms of the lines of Salter, but also address their seasonal aspect by comparing samples collected from the Southern Hemisphere and rely on measurements rather than manual counting for the estimates. Finally, all these efforts aim to maximize the potential of the cementochronology technique and to justify its use in the forensic arena.

Keywords: tooth cementum annulation; age estimation; forensic odontology

O44

Micro-CT-investigation of rare dental anomalies in two sympatric European bat species (*Pipistrellus* spp.)

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In the literature there are some indications of minor teeth alteration in bats, such as teeth that have been severely chewed off due to age as well as duplication or absence of single tooth positions. Also parodontitis which may result in teeth loss is reported in the genus *Pipistrellus*. Most of this information is from museum collections, which provide an invaluable source of data.

Beside this, we documented striking anomalies in the dentition of the Common Pipistrelle (*Pipistrellus pipistrellus*) during field work over the past twenty years. As these bats had been completely vital individuals they were released after photographic documentation. In contrast in 2019 we received two bat nurslings from the Rhine-Main area (Hesse, Germany), each with a notable and ultimately fatal anomaly: a Common Pipistrelle (*P. pipistrellus*) with a teeth aberration and a Pygmy Bat (*P. pygmaeus*) with an aberration of the right mandible and maxilla including missing teeth.

We examined these defects non-destructively using high-resolution 2D and 3D X-ray methods at the Senckenberg 2D-Xray and CT-Lab Frankfurt/Main. 2D-radiographs of the bats were done on digital imaging plates with the Faxitron HP (50kV, 3mA, 60-90s), which were read in with a DÜRR laser scanner (resolution 7µm). The µCT- scans were performed with the ProCon-X-Ray-Micro-CT (90kV and 89µA with 2,400 projections), and the data (7.5µm voxel size) segmented with VGStudio MAX 3.4.

After the bat population in Germany had demonstrably stabilized since the 1980s, habitat changes (intensified agriculture, wind turbines, urbanization, insect mortality) pose new threats for the insectivorous animals. There is currently a lack of systematic investigations as to whether these tooth anomalies and diseases are normal evolutionary processes or related to the current environmental conditions. For further investigations (e.g. DNA, toxicology, EBLV) all X-rayed bats of our study will be kept in the museum collection.

Keywords: dental anomalies; high-resolution 2D-Xray; Micro-computed tomography; *Pipistrellus pipistrellus*; *P. pygmaeus*

Poster presentations

Abstracts are in numerical order.

P01

Patterns of incisor and first permanent molar development in modern humans, great apes and early fossil hominins.

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Developing teeth pass through successive stages of formation. Patterns of dental development result when in several developing dentitions two or more teeth at different stages of formation consistently coincide with each other. However, the pattern, or sequence, of dental development varies both between individuals and between taxa. Our aim was to quantify the variation in modern human and great ape incisor formation stages that occur first, when M1 root is between a half formed ($R\frac{1}{2}$) and three quarters formed ($R\frac{3}{4}$) and second, when M1 root is between three quarters formed ($R\frac{3}{4}$) and root complete (RC). We identified eleven early fossil hominins at these stages of M1 root formation and compared the pattern of incisor / M1 formation stages with those observed in modern humans and great apes. We defined 14 stages of tooth development and scored each developing tooth on radiographs of 162 once free-living great apes and on orthopantomographs of 4045 dental patients aged 1-23 years. Tooth formation stages in the fossil specimens were scored from published radiographs and/or micro-CT or synchrotron scans or from direct observations of the specimens. At M1 stages $R\frac{1}{2}$ and $R\frac{3}{4}$, great ape incisor development was relatively delayed compared with humans but there was overlap in the incisor stages observed. Five fossil hominins were at stages of incisor development observed in both humans and great apes. However, five fossil hominin specimens were at a relatively advanced stage of LI1 development, beyond the range of stages observed in the great ape sample. At M1 $R\frac{3}{4}$ and RC, one fossil hominin specimen (KNM-KP 34725, attributed to *Australopithecus anamensis*) showed delayed incisor development greater than that observed among the human sample. Another (LH3, attributed to *Australopithecus afarensis*) was at the earliest, most delayed, incisor stage observed among humans. With these two exceptions, no other fossil hominins fell beyond the range of incisor formation stages observed in our human sample.

P02

Chronology of the medieval population of Gevensleben assessed by dental enamel microdefects

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The Gevensleben burial ground was used as an early Christian cemetery in the 8th-10th century. It represents an important source for the social and cultural history of the ordinary population of the early Middle Ages in Lower Saxony. Archaeological and anthropological investigations during 2016 and 2018 have already revealed information about the people buried there. The histological examination of the dental enamel supports and expands these data.

Tooth enamel undergoes a periodic development which reflects the incremental secretion enamel of ameloblasts. This development reacts to stressful events with the forming of accentuated Retzius lines. These microscopic enamel defects can be analysed by histological thin sectioning of individual teeth.

For this purpose, we selected 30 teeth sets from 10 individuals buried in Gevensleben. Each tooth gives a record of around 2 years of development during its growth while still in the jaw. To cover the first years of each individual, we chose multiple teeth from this person and matched the age-dependent data.

Histologic thin sections of the teeth were digitized with a digital camera in combination with a light microscope. An individual chronology of each tooth was assessed. By matching accentuated Retzius lines in different teeth of the same individual, we reconstructed the first years of this person's life.

P03

Testing the presence of sexual dimorphism in radicular dentine thickness and topographic distribution in modern human upper permanent canines

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Sexual dimorphism has been revealed in the permanent canines of modern humans, with males showing larger crowns than females. The study of tissue proportions also showed absolutely and relatively greater volumes of coronal dentine in males, whereas a greater proportion of the crown is constituted by enamel in females. Differences in physiological and genetic control of tooth development could explain this sexual dimorphism.

The aim of the present study is to test whether the pattern of sexual dimorphism seen in coronal dentine can be extended to the radicular dentine of upper permanent canines, both in its absolute and relative proportions but also in its local topographic variation.

Absolute and relative volumetric variables expressing tissue proportions were measured on a microtomographic record of 50 upper permanent canines (voxel size ranging from 18 to 51 μm) of 30 males and 20 females from two South African contemporary identified osteological collections and two French medieval cemeteries. To assess the distribution of radicular dentine thickness, we virtually unrolled a region of interest comprised between 50% and 90% of the total root length (0% being at the apex of the root, and 100% at the cervix) by applying a new R package, *morphomap*, for two- and three-dimensional morphometric mapping.

Results from the Wilcoxon rank tests show that males and females statistically differ (p -value < 0.05) in their absolute volumes of radicular dentine at the level 50-90%, whereas no statistical difference is observed when the volume of dentine is calculated relative to the pulp cavity. The standard Principal Component Analysis based on the 2D morphometric maps of dentine thickness shows a complete overlap between males and females, indicating similar patterns of dentine distribution along the root in both sexes.

P04

Wild boar vs domestic pigs – A deep dive into tooth crown formation

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We reconstructed crown growth parameters of mandibular second molars in wild boar and domestic pigs (Linderöd breed) based on the analysis of growth marks in labelled forming enamel. Body weight gain and progression of dental development were markedly faster in the domestic pigs than in the wild boar. While the final crown dimensions of the M₂ did not differ between domestic pigs and wild boar, mean crown formation time (CFT) of this tooth was considerably shorter in the domestic pigs (161.5 days) than in the wild boar (204.5 days). The difference in CFT was mainly attributable to higher enamel extension rates (EERs) in the domestic pig molars (mean values of 96.4 µm/day in buccal and 150.2 µm/day in lingual enamel) compared to those of wild boar (mean values of 75.7 µm/day in buccal and 126.3 µm/day in lingual enamel). Generally, EER was very high in the cuspalmost deciles of the EDJ length and markedly dropped in cervical direction, with lowest values (wild boar: 23.1; domestic pig: 28.3 µm/day) occurring in the cervicalmost decile. In consequence, the cuspal half of the M₂ crown was formed up to three times faster than the cervical half. In contrast, no marked differences were recorded for daily enamel secretion rate (DSR), the duration of secretory activity of ameloblasts and linear enamel thickness in corresponding crown portions between domestic pigs and wild boar. Thus, the earlier completion of M₂ crown growth in the domestic pig is mainly achieved by a higher EER and not by variation in DSR. The recorded more rapid recruitment of secretory ameloblasts in the course of molar crown formation of domestic pigs compared to wild boar is considered a side effect of the selection for rapid body growth during pig domestication.

P05

Marked discrepancy between dental and skeletal development associated with pathological conditions: a case report

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We report a case of an unusually marked difference between dental and skeletal development in a juvenile individual from the Late Bronze Age (circa 1200 BC) site of Tell Chuera, Syria. Two juvenile skeletons (individual A: presumably female, individual B: presumably male) of similar dental age were studied. The reconstructed skeletal age of individual A deviated strongly from its dental age, indicating a marked (several years) retardation of skeletal compared to dental development.

In both, according to different schedules of tooth formation the dental age at death was 15 +/- 3 years. In individual B, radius length of 225 mm as well as the remaining analyzable skeletal indicators are in accordance with an age of about 13-15 years. In contrast, the skeletal indicators of individual A present a mosaic of mainly a delay with corresponding ages as low as 7 years (e.g. radius length 155 mm, ischiopubic ramus unfused, wrist, sacrum, pseudoepiphyses in metacarpals and metatarsals) and few regular (e.g. fusion state of the dens axis and foot phalanx epiphyses) states of skeletal compared to dental development.

Additionally, individual A exhibited various pathological conditions, including cortical rarefaction of the vertebral bodies and pit-type enamel hypoplasia along with discolored enamel of the postcanine teeth except for the M1s. The fact that the front teeth and the M1s showed no pathological changes indicated a childhood onset of disturbed tooth formation, which would be in line with a postnatally acquired rather than a congenital developmental disorder. The occlusal facets of the M2s of individual A were larger than those of individual B. More advanced wear and discolored enamel suggest that the disturbance of tooth formation in the former included an impairment of enamel maturation. A study analyzing whether the assumed enamel hypomineralization had caused differences in dental microwear between the two individuals applying a 3D approach is currently under way.

Keywords: growth delay; dental age; pit-type enamel hypoplasia; developmental disorder; tooth wear

P06

Facial asymmetry and chewing sides in twins

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The objectives of this study were to resolve how the preferred chewing side (PCS) affects facial asymmetry in twins, whether there are differences between monozygotic (MZ) and dizygotic (DZ) twins, and whether the twins with PCS have more asymmetric faces compared to symmetrically chewing twins.

The study included 106 Lithuanian twin pairs of the same sex, 59 MZ pairs and 47 DZ pairs. The faces of the twins were recorded by a 3dMDFace system (3dMD, Atlanta) based on stereophotogrammetry technology. The chewing side preference was first studied by asking. If the subject was not able to give an answer, they were asked to chew gum and their chewing was followed visually for a minute by the researcher. If the result was unclear, the test was repeated. If the result did not become clear even then, it was recorded that the subject used both sides for chewing.

We also developed a new method for measuring chin asymmetry from the facial 3D model, called Chin Volume Asymmetry Score (CVAS). The data was analyzed from facial 3D images and manually added landmarks. 3D images were analyzed by Rapidform2006 software and statistical analyses were done by using the R software environment version 4.1.0. Effect of chewing side preference on larger chin side was explored by using generalized linear mixed model with logit link function. Facial asymmetry between symmetrical and asymmetrical chewers was compared with linear mixed model. Possible genetic effect on PCS and facial asymmetry was examined by comparing pairwise tetrachoric and intraclass correlations between MZ and DZ twins.

The results showed that the contralateral effect of PCS and larger chin side was dominant among right and non-right side chewing twins. Being female increased the whole face symmetry. As a conclusion, the volume of the chin becomes larger on the side opposite to the twins' habitual chewing side. As the results are quite similar in both twin types, functional factors are more prominent than heredity. Supported by EOS grant.

P07

New analysis of Nolla's longitudinal radiographic study.

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Aims: Carmen Nolla (1952, 1960) was early to define and collect data on development tooth-by-tooth rather than by atlas, yet at the time, approaches to analysing such data were in their infancy. The aims of this study were to re-illustrate and describe permanent tooth stages for Nolla's seminal work and to analyse data on age of attainment of tooth stages captured from her thesis. Materials and methods: Descriptions and drawings of tooth stages were made from radiographic examples for each stage of permanent teeth in the maxilla and mandible, matched to Nolla's originals. Longitudinal data of tooth stage for age for 25 boy and 25 girls aged 2-18 years were captured from graphs in Nolla's Master's thesis from The University of Michigan School of Dentistry. Mean ages of attainment of tooth stages were analysed using transition analysis in R. Results: Drawings and descriptions for the ten Nolla stages for the permanent teeth are presented here with radiographic examples. Mean ages of attainment for individual maxillary and mandibular teeth calculated here were overall somewhat earlier than previously published ages from other longitudinal radiographic studies. As expected, attainment of tooth stages in girls was marginally earlier than boys and mandibular incisor stages were earlier than maxillary incisor stages. Conclusion: A new illustration of Nolla tooth stages with drawings, radiograph and descriptors is now available. New reference data of mean age of attainment for this group of children corrects values from 1960, including rarely available maxillary data.

P08

The association between Retzius periodicity and adult height in modern New Zealanders.

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During formation, dental enamel is sensitive to a multi-diem biorhythm, evident histologically as regular striae of Retzius. Striae of Retzius periodicity (RP) reflects the pace of the biorhythm, identified by the number of daily enamel increments between adjacent striae.

The biorhythm represented by RP has been positively correlated, interspecifically, with variation in body mass, but negatively correlated with certain growth variables in humans. Here, we investigate possible relationships between RP and adult height and weight in 54 modern New Zealanders.

Anterior teeth had a significantly higher mean RP compared to molars ($t = 5.123$, $df = 53$, $p < 0.001$). When molars and anterior teeth were analysed separately, no linear associations were detected between RP and male and female Z-scores for either height or weight data. Curve fitting suggested a positive relationship between RP and adult height Z-scores in anterior teeth only, which was best described by a quadratic regression curve (R square = 0.600, $F = 5.993$, $df1 = 2$, $df2 = 8$, $p = 0.026$). When anterior teeth and molars were collectively analysed, a positive correlation was detected between RP and male height only ($\rho = 0.519$, $n = 20$, $p = 0.019$).

Tentatively, our results suggest a positive association between RP and adult height similar to that observed interspecifically. However, we found the relationship may best be captured by a quadratic curve, suggesting a more complex relationship between RP and adult height than represented by a simple linear association. We discuss the importance of analysing RP by tooth type as well as consider possible limitations of our study.

P09

Perinatal tooth eruption in precocial and altricial rodents and lagomorphs

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Perinatal tooth eruption in mammals is highly constraint by the mode of postnatal development in terms of altricial versus precocial adaptations. The timing of this event in small mammals is still obscure in many taxa due to technical limitations as it can be best investigated by histology. Rodents and lagomorphs are suitable case studies as both orders comprise altricial as well as precocial species. Lagomorphs and especially rodents use their incisors not only for gnawing but also for exploration and thus early eruption can be postulated. Furthermore, in altricial species tooth eruption of cheek teeth should be delayed after birth compared to precocial species.

For the present study perinatal stages of altricial (*Mesocricetus auratus*, *Peromyscus maniculatus*, *Mus musculus*, *Micromys minutus*) and precocial rodent species (*Petromus typicus*, *Thryonomys swinderianus*, *Octodon degus*, *Chinchilla lanigera*, *Myoprocta pratti*, *Cavia porcellus*) as well as two lagomorph species, the altricial *Oryctolagus cuniculus* and the precocial *Lepus europaeus*, were investigated by histological serial sections.

In altricial rodents eruption of incisors and molars is restricted to early postnatal stages. However, *Mesocricetus* has the shortest gestation period among placentals (15-17 days) but clearly shows a prenatal eruption of incisors. In precocial rodents the incisors erupt in prenatal stages before or at the same time as the first cheek teeth. In general, the sequence of cheek tooth eruption in the investigated rodents is from anterior to posterior. *Cavia* and *Chinchilla* show a puzzling pattern as the first molar erupts before the premolars, and in the former even before the incisors. In both lagomorph species the incisors erupt before birth. The timing of cheek tooth eruption resembles the pattern in rodents, where altricial species show postnatal eruption of cheek teeth in contrast to precocial species that are born with at least partly erupted cheek teeth. However, the first upper cheek tooth (dP2) in lagomorphs shows a delayed eruption compared to all other deciduous premolars.

P11

Accessory cusp expression in hominoid mandibular molars

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Hominoid mandibular molars frequently display accessory cusps, particularly on the distal margin of the tooth (distal accessory cusp/C6) or the lingual margin of the tooth (lingual accessory cusp/C7). These presence, location and morphology of these cusps is utilised in studies of hominin systematics, where they are typically assessed at the enamel surface. However, studies of the enamel-dentine junction (EDJ) suggest that these traits may be more variable in development, morphology, and position than previously recognised. Here I score the expression of accessory cusps in extant apes (*Pan*, *Gorilla*; $n = 106$) and Plio-Pleistocene hominins (*Paranthropus*, *Australopithecus*, and *Homo*; $n = 115$) using a scoring procedure that considers the relationship between accessory cusps and the surrounding primary cusps. There are taxon-specific patterns in the EDJ expression of these traits; molars of *Pan* and *Paranthropus* typically have one or more distal accessory cusp but no lingual accessory cusps, while the opposite pattern is found in *H. habilis* M1s and M2s. Meanwhile *Gorilla* molars most often do not have accessory cusps. However, there are also a number of complicating factors. Some apparent accessory cusps at the enamel surface are represented at the EDJ only by ‘shouldering’ on the ridges associated with the main cusps, while other accessory cusps appear to have little or no EDJ expression at all. Shouldering features are highly variable in morphology, and in some cases are found closely associated with ‘true’ accessory cusps. The developmental basis of shouldering and enamel-only cusps is uncertain, and in particular, it is not clear whether these features are initiated by enamel knots. This means they may not be developmentally homologous to ‘true’ accessory cusps and would need to be considered separately when used for taxonomy or phylogeny. These results underline the importance of assessing the morphology of the enamel-dentine junction as well as the enamel surface wherever possible.

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P12

Effective low-cost high-resolution replicas for light scanning and topographic analysis of dental crown.

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When performing high-resolution replicas, there are a large several options of casting materials depending on the techniques used for analysis. In this contribution we will address casting materials aimed to the reconstruction of 3D virtual models using a high-resolution surface scanning system.

For acquiring the 3D model, we use an intraoral scanner i500 Medit (Staubmann Group), designed for dentistry. It is capable of accurately record the surface with a precision of $3.2 \text{ microns} \pm 0.49$.

Transparent epoxy resins are the most commonly material used, which must be coated with talcum powder or ammonium chloride fog providing an opaque appearance that allow scanning, obstructing the posterior use of the replicas with other methodologies, for example, microwear analysis. Another practice is to use dental stone which allow a fast and low-cost replication but a poor performance regarding reproduction of the details. With an increase of accuracy and trueness in scanning, we are needing more reliable materials than can replicate the details preserved on the mold.

Polyurethane resins have been demonstrated to have great precision (i.e., dental microwear), and are low-cost compared to epoxy resins. We tested four different types, based on their curation time from few minutes to 2-3 hours. The performance under the scanner was similar in all cases. The process of producing the replica is what separate them. Polyurethane generates an exothermic reaction while curing, and the fastest the process is, the highest temperatures are reached, to the point of even damaging the molds, erasing some of its details. If the resin cures within 2-3 hours, no damage has been observed on the mold, and it can be re-casted without appreciating any difference.

The advantages of using this material over epoxy resin are the low-cost, excellent reproduction of the details also allowing studies on morphology, analyses with optical microscopes, SEM, etc.

P13

Looking below the surface of highly complex Cave Bear Molars

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Cave bear (*Ursus spelaeus*) is an iconic extinct bear species that inhabited Europe and Western Asia until the last glaciation. They evolved a specialized dentition with large molars having broad masticatory surfaces and many low rounded cusps. As tooth shape correlates with feeding behavior, progressive complication in the cheek teeth is thought to imply a heavy dietary reliance on tough plant matter. Because tooth enamel is rarely uniformly distributed across the occlusal surface, it raises the question how much of the exceptionally high complexity of the cave bear molars can be attributed to the enamel distribution or, alternatively, to shape of the underlying enamel dentine junction (EDJ).

We scanned the second upper molar teeth of cave bears with 3D X-ray microtomography (μ CT). Using the μ CT scans, we reconstructed both the enamel and EDJ shapes. Orientation patch count (OPC), curvature and enamel thickness were used to compare the shapes. Nutrient-limited model of enamel matrix secretion and geometric extrapolation of the enamel surface was used to examine variation in enamel distribution. The results show that the high complexity of cave bear molars is not a simple geometric extrapolation of the enamel from the EDJ. Rather, subtle features of the EDJ are magnified on the enamel surface, suggesting that the high complexity of cave bear molars is largely accomplished during the enamel matrix secretion phase of tooth formation.

P14

In hypodontia some morphological parameters of premolars and molars vary with different sites of the congenitally missing teeth

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BACKGROUND: Hypodontia is a complex condition involving not only congenitally missing teeth but also variations in the size and morphology of the formed teeth and of the craniofacial complex. The aims of this study were to explore if some morphological parameters of premolars and first permanent molars vary between: 1. hypodontia patients and matched controls, 2. patients with hypodontia of incisors and those with hypodontia of premolars and molars, and 3. males and females within groups.

MATERIALS AND METHODS: Study models of 51 hypodontia patients and 51 controls were measured using 2D image analysis. Of the hypodontia patients 26 had absence of incisors and 25 had absence of premolars and molars. The parameters scored were: intercuspal distances on premolars and first permanent molars; the presence and size of Carabelli cusp on maxillary first permanent molars; and the number of cusps on premolars and molars.

RESULTS: Intercuspal distances were significantly smaller in premolars in hypodontia patients than in controls ($p=0.02$), with these differences more marked in the incisor hypodontia group. In maxillary first permanent molars significant differences in intercuspal distances were only seen in females of the incisor hypodontia group ($p=0.03$). Overall there was a weak negative correlation ($r=-0.33$) in hypodontia cases between metacone-protocone distance and the size of Carabelli cusp in maxillary first molars, but in the incisor hypodontia patients the negative correlations were higher, being strongest in females ($r=-0.74$). Hypodontia patients were less likely to have a Carabelli cusp present ($p<0.001$); in those hypodontia patients where the cusp was seen it was smaller than in controls ($p=0.03$, OR= 9.02).

CONCLUSIONS: The parameters investigated varied between: 1. hypodontia patients and controls, 2. patients with hypodontia of incisors and hypodontia of premolars/molars, and 3. males and females. These findings reinforce that the phenotype of hypodontia is the outcome of a complex adaptive system in which many factors influence morphological patterning.

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Keywords: cusp numbers; intercuspal distances; hypodontia

P15

The evolutionary transition from the second to the first molar dominance

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The upper second molar is thought to be the dominant tooth in Neanderthals, in contradistinction to recent modern humans, among whom the first molar is dominant. It is not known, however, whether molar dominance is population dependent or whether this feature has evolved over time.

In this study, we aimed to explore differences in molar dominance in the Holocene Levantine populations.

66 specimens were included in the study, each having both upper first and second molars with minor degree of occlusal attrition. The sample was composed of 25 recent modern human (RMH), 23 modern human, 4 anatomically modern human, and one from Misluya.

Upper first and second molars were scanned using Micro-CT, segmentation and 3D reconstruction of the scans were carried out using Amira software. Centroid size, crown morphology, and relative cusp area measurements were further analyzed using EVAN Toolbox, and Rhinoceros 5 softwares. Geometric morphometric analysis was performed using PAST software and Principal Component Analysis (PCA) was carried out to examine the shape variation. We found that in all studied populations, the first molar was significantly larger (i.e., centroid size, coronal dentin volume, and EDJ surface area) compared to the second molar ($p < 0.05$). A gradual decrease in first molars size parameters was found between RMH towards more ancestral populations ($p < 0.05$), however, no such difference was found in the second molar.

The reduction in tooth size effected all cusps equally and was could not be attributed to a specific cusp ($p < 0.05$).

Our findings implies that the first molar undergoes significant changes in size and form throughout evolution, whereas this trend is less pronounced in the second molar. Although the first molar is considered as the dominant tooth in the studied populations, the second molar is probably more stable thorough time.

P16

Cusp 6: world variation on the lower first and second molars and possible link to EDAR v370a

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Cusp 6, also known as *tuberculum sextum* or the entoconulid, is an ancient crown trait exhibited on the lower molars of hominoids going back to the Miocene. In Plio-Pleistocene hominins, it is more common in *Paranthropus* than *Australopithecus* or early *Homo*, especially on LM1. For early hominins, the trait is more common on LM2 and LM3, in line with the size sequence of LM3>LM2>LM1. The frequency of cusp 6 in modern human populations is highest for LM1 associated with the reversal of the primitive size sequence, although trait expression is more pronounced on LM2. World variation in LM1 cusp 6 shows a primary division between Europe and Africa, with low trait frequencies (5-15%), and Asia and Asian-derived groups, with moderate to high frequencies (30-60%). These frequency distributions mirror the variation in U11 shovel-shaped incisors. Researchers have found a SNP in the *EDAR* signaling pathway (*v370a*) associated with shoveling and lower molar cusp number. These aligning global variations support the proposition that this SNP is implicated in cusp 6 variation. However, as with shoveling, Australia and New Guinea are exceptions. Both groups lack *EDAR v370a*, but cusp 6 is very high in Australians (65%) but low in New Guinea (10%). Other signaling factors or SNPs must be involved to account for this contrast. In addition to *EDAR*, the gene families *SHH*, *BMP*, *FGF*, and *WNT* play primary roles in the signaling pathways involved in dental development. Updated cusp 6 world variation may implicate other target gene families or SNPs to investigate.

P17

Kinship and mortuary practices at the ancient Greek colony of Chersonesos (Crimea): Insights from dental morphology

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The city of Chersonesos (today Sevastopol) was founded in the 5th century BC on the coast of the Crimean peninsula in the northern Black Sea region, allegedly by colonists from ancient Greece. Numerous archaeological investigations tackled the question of how Greek colonists interacted with local Taurian tribes and whether both groups were buried together at Chersonesos. Relying on mortuary practices as an indicator of the ancestry of the deceased, it was hypothesized that individuals in flexed burial positions were Taurian, whereas individuals in extended burial positions were Greek. Here we test the hypothesis that individuals in flexed and extended burials are biologically different by directly analyzing the skeletal remains. For this, we perform a non-invasive biodistance analysis, using a dataset of skeletal phenotypes considered heritable and selectively neutral. The dataset consists primarily of dental mesiodistal and buccolingual crown and cervical diameters and dental non-metric traits of the Arizona State University Dental Anthropology System. Using Gower coefficients, we estimate inter-individual distances among 8 flexed and 13 extended burials and perform a distance-based permutational multivariate analysis of variance (PERMANOVA) and dispersion (PERMDISP). Both analyses show that there are no statistically significant differences between the two groups, neither in group centroids nor in group dispersions. This result challenges the widely held opinion that burial position at Chersonesos was determined by the ancestry of the deceased. This has implications for future archaeological research at Chersonesos and other Greek colonies of the northern Black Sea region. More broadly, this study provides a conceptual template for analyzing scarcely sampled mixed data from dental phenotypes in an individual-level biodistance framework.

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P18

Easter Island: what does dental morphology tell us about possible biological impact from the Americas

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Easter Island, with its unique moai, has long intrigued scientists and the lay public alike. How did people arrive on this island far removed from Southeast Asia, central Polynesia, and the Americas? Early explanations have been dismissed as all agree highly skilled Polynesian navigators guided their outriggers to Rapa Nui, the local name for the island. That has not quelled speculation, initially promulgated by Thor Heyerdahl and his Kon Tiki expedition in 1947, that the island was culturally and/or biologically impacted by natives from the west coast of South America. In 1952, Heyerdahl produced a tome entitled “American Indians in the Pacific” in which he marshalled archaeological and paleobotanical evidence to support his theory. Recently, genetic data have been brought to bear on this question. If Native Americans made it to Rapa Nui, can we see it in their genes – some researchers say yes, others say no. Our goal is to bring another line of biological evidence to the question – does dental morphology provide any hint that Native Americans contributed to the gene pool of Easter Island? A biodistance analysis of 15 crown and root traits yielded ambiguous results. When Bray Curtis dissimilarity measures are portrayed in dendrograms, Easter Island clusters with four Native American populations. Dendrograms based on Euclidean distances have Easter Island clustering with four Polynesian populations, although it is the most divergent group in the cluster. At present, it is hard to disentangle the contributions of gene flow or genetic drift to this result. Unfortunately, there is no ‘smoking gun’ like the Uto-Aztecan premolar that would show a definite sign of Native Americans having a biological impact on Easter Islanders.

P19

Maxillary lateral incisor mesial bending in Medieval populations from the Iberian Peninsula

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Anatomical variations of teeth are used to comprehend population interactions, migrations, and establish geographic/biological origins and affinities of ancient and recent human populations. So, dental morphology is a good indicator of past population dynamics.

Maxillary lateral incisor mesial bending is a rare trait—also known as “Etruscan Upper Lateral”— that is observable as a concavity on the mesio-lingual border of the middle portion of the upper lateral incisors, which can vary in both extension and depth. To date, this trait has been studied on global scale and a regional, especially in Italy, where it is a relatively common trait from the Late Pleistocene to the recent past. Aiming to evaluate the frequencies of this trait in southwestern European populations, 156 maxillary lateral incisors were analyzed from six Medieval Period (8th to 15th centuries) archaeological sites from the Iberian Peninsula. According to the funerary context, the sample is composed of two culture groups: Christian (n=72) and Islamic (n=84). Results show that higher frequencies of bending ($X^2=5.3$; $p=0.022$) are present in the Christian group (20.8%; 15/72) when compared to the Islamic (9.5%; 8/84) one. The results of the current investigation suggest that maxillary lateral incisor mesial bending reflects some degree of biological continuity and admixture between the southeastern Mediterranean Europe, western Iberia, and northwestern Africa. Little is known about the antiquity of this dental trait outside of the Italian Peninsula, thus whether the presence of the trait is an early or recent arrival in Iberia and North Africa will need further exploration. In future studies aim to standardize the trait recording methodology and to add data from other regions and chronologies to better understand the spatiotemporal patterning of this trait within the context of past human population dynamics in southwestern Europe and North Africa.

P20

The co-occurrence of rare nonmetric dental traits in Middle Holocene burials from Toca do Enoque support intrasite family relationships

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During excavations at the prehistoric (Middle Holocene, c. 6000 – 5000 BP) burial site of *Toca do Enoque*, in Northeast Brazil, three burials were exhumed that contained 12 individuals: two probable female young adults, one middle-aged male, and nine non-adults.

We presume genetic kinship based on dental traits that stand out for their rarity and high heritability: barrel-shaped upper lateral incisors (grades 6 and 7 on UI2 shoveling scale) and premolar odontomes. In the absence of aDNA results due to the lack of collagen in the bone tissue, we chose a methodology based on non-metric dental epigenetic traits that are useful for the reconstruction of biological kinship in past populations.

Of 12 skeletons, we analyzed the permanent teeth of seven individuals. Exclusion criteria were age-at-death (< one year old) and the absence of observable teeth. The methodologies proposed by Vach & Alt (1992) and Alt & Vach (1995) were used in the dental kinship analysis, which seeks to establish presumptive genetic relationships based on the observation of rare heritable dental traits.

The relative frequencies of rare dental traits observed were high. Barrel-shaped (shoveled) upper lateral incisors (grades 6-7) reached a frequency of 33.3% while odontomes had a frequency of 16.7%. These high frequencies support the hypothesis of genetic kinship among individuals who were buried as a family group. The hypothesis was tested with dental kinship analysis and validated with archaeological data such as spatial distribution and funeral treatment. Additionally, the relative frequencies from others Brazilian archaeological sites (*Corondo*, *Sambaqui North*, *Sambaqui South* and *Lagoa Santa*) were much lower than *Toca do Enoque* for barrel-shaped upper incisors (6.0 %) and premolar odontomes (6.4 %). The identification of rare dental traits in individuals from the same burial site likely indicate genetic kinship ties.

Keywords: dental kinship analysis; genetic kinship; rare dental traits

P21

Tip of lower incisors of rodents: measurements of the angle of the lower incisor tip as wedge angle

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Rodents are the second most diverse group of mammals and probably their dentition with a large diastema and in particular, their incisors are the base of this success. The two upper and lower incisors (one in each jaw quadrant) are ever growing and only labially (buccally) covered by enamel whereas the main body consists of dentine. The difference in hardness between these materials as well as constant use enable the maintenance of a sharp cutting edge. In the presented study, the tip of the incisors is analyzed in more detail across some representatives of rodents (selected according to availability in our collection). In action, usually the lower incisor acts as cutting tool (wedge) and the upper incisor as bolt. Therefore measurements of the lower incisor tip angle (wedge angle). Some tests were performed a) with teeth in dried skulls photographed so that the labial edge of the enamel of the incisor is parallel to the lens and the angle measured by hand on the printed photos; and b) with incisors embedded in epoxy resin and cut vertically in the midline and photographed with the SEM. Again photos were printed and the angle of the tip measured by hand. The tests were performed to get an idea about the error range of the measurement between methods and between observers with teeth of different size range. The ideal measurement of the angle would be by μ ct-scan, adjusted so that the angle can be measured exactly in the midline of the tooth and with the line really along the enamel of the tip. This method is not applicable to all specimens and so comparable results obtainable without μ ct-scans are desirable. It is hypothesized that a range of error can be determined so that a correction factor can be given to the measurements of the incisor tip. It is also assumed that the range varies with the size range of incisors, decreasing with their size. As for the angle of the incisor tip (wedge angle) it is assumed that it is close to the technically ideal wedge angle of 27° (under certain conditions) in all species; closer to it in species which gnaw (or dig) harder objects/substrates.

P22

Standardization of dental complexity measurements using OPC

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The complexity of mammal molars is a trait intrinsically linked to diet. Quantifying such a trait is difficult within the realm of traditional morphometrics, and hence researchers working on dental topographic analysis developed the Orientation Patch Count (OPC) as a measure of dental complexity. OPC can be performed on varying types of three-dimensional scans of teeth and has seen wide use; most often employed to infer diet from molar morphology. Consequently, there is a considerably variety of software solutions for measuring OPC and myriad protocols regarding input data, which has led to few OPC results being directly comparable between publications. Here we seek to expand the usage of OPC by developing a standardization scheme, which can easily be applied to a variety of contexts — whether paleontological, developmental, or something else altogether — and which strives to facilitate easier comparisons between studies. The aim is to enable a conversion of OPC values of different studies to a common unit measure that is relatively robust against differences in data acquisition, processing, and software used to measure OPC. Additionally, we show auxiliary analyses of the OPC maps that allow downstream analyses of tooth shapes from the point of function and development.

P23

A distance-based comparison method for measuring occlusal tooth wear from dental 3D models

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Tooth wear refers to loss of dental hard tissue during everyday functioning by means other than dental caries. Prevalence of tooth wear is quite high, and everyone are expected to have it at a certain level. Tooth wear can be easily observed but measuring its amount accurately can be problematic.

Dental 3D models have been used recently for measuring dental loss. 3D tooth has been divided by plane so that volume for solid figure of tip of tooth can be calculated. Problem in volume calculation is that it demands closed 3D surface. Many teeth are in approximal contact and the area of contact surface can change as time passes. In this case, volume comparison can be flawed. We suggest that the comparison of dental surfaces is measured by distances between the vertices of the base surface including portion of the crown between the approximal contact points and gingival margin and the closest points on comparable surface. This avoids the problems in volume calculation affected by gingival withdrawal or some other irregularity between the dental surfaces.

Examining the superimposition of 3D surfaces is essential in 3D tooth comparison. Iterative closest point algorithm is traditional way for surface registration. It is not recommendable to use complete crown as reference area in the superimposition, but one should use the areas remaining unchanged. Choosing the reference area by hand would be very time consuming while exploring large sample, so we also examine different ways to choose the reference area automatically. We will test our distance-based comparison method and automated reference area selection for real sample. Sample is from 12-year follow-up study based on the Northern Finland Birth Cohort 1966 (NFBC1966). 72 3D dental models were found from two time periods.

P25

Life history in the primate skeleton is revealed by changes in major and minor element concentrations measured via field-emission SEM-EDS

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The histological analysis of mineralized tissues has been extensively used to investigate the life history patterns of extinct and extant taxa. However, non-cyclic histological markers are non-specific indicators of changes in the organisms' energy and mineral balance. In this work, we address this limitation by performing elemental analysis of the dental cementum and primary femoral lamellar bone of seven rhesus macaque (*M. mulatta*) individuals with associated medical and life history records. We employ field-emission scanning electron microscopy and energy-dispersive X-ray analysis to measure the relative concentrations of calcium, phosphorous, oxygen, magnesium and sodium in 34 teeth and seven femora, representing both males and parous and nulliparous females. We find that changes in relative magnesium concentrations identify breastfeeding in infants in both cementum and bone, as well as differentiating between pre-natal and post-natal bone. Additionally, as expected, we find that changes in calcium and phosphorous concentrations in bone, but not in cementum, are associated with reproductive events in females. Finally, we observe that the elemental composition of both cementum and bone in parous females is different from that of age-matched nulliparous females and males. Overall, we find evidence for the same systemic response of the organism across different skeletal elements (cementum and bone) in relation to reproduction and suckling. These observations can be used to help identify the cause of histological markers and therefore contribute to reconstructing life-history profiles via the analysis of mineralized remains.

P26

Characterization of abnormal cheek tooth wear in fluorotic dentitions of the European roe deer (*Capreolus capreolus*)

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Ruminants rely on mastication to process their food for subsequent microbial breakdown. During the power stroke of mastication, the mandibular cheek teeth slide over their maxillary antagonists on one side of the dentition and the plant material is subjected to slicing and grinding between the enamel ridges of the opposing occlusal surfaces. Ruminant cheek tooth function is compromised following excessive fluoride intake during tooth development, which causes pathological changes in enamel (enamel fluorosis). We studied fluorotic lesions in the enamel of permanent cheek teeth of European roe deer and the sequelae of these lesions in the affected dentitions. Fluorotic enamel was hypomineralized and exhibited abnormal opacity and posteruptive staining due to its increased porosity. The reduced hardness of fluorotic enamel caused a diminished resistance to abrasion/attrition, leading to a reduction in height or even complete loss of the enamel ridges on the occlusal surfaces of the affected cheek teeth and excessive dental wear. The intensity of pathological changes varied in a systematic way among the permanent cheek teeth of severely fluorotic dentitions. While the permanent premolars and the third molars typically exhibited marked enamel lesions and grossly abnormal wear, the first molars were not or only slightly affected and the second molars showed an intermediate degree of pathological changes. We propose an explanation for this pattern that is based on the developmental sequence of the permanent cheek teeth in roe deer. It is suggested that due to mechanisms that limit the transfer of fluoride from mother to fetus/fawn (partial placental barrier to fluoride and partial blood-milk barrier), cheek teeth whose crowns form entirely (M1) or partly (M2) pre-weaning are less affected than teeth (P2-4, M3) whose crowns form entirely after weaning when the individual feeds on F-contaminated plants. Supporting evidence for this hypothesis from fluoride profiling in dentin is presented.

P27

Non-occlusal dental microwear texture analysis of a somphospondyli titanosauriform sauropod dinosaur from the Tamagawa Formation, northeastern Japan.

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Dental microwear, microscopic scars on tooth surface left by tooth-tooth and tooth-food contacts, have been used to reconstruct the diet and jaw movement of extinct vertebrates. The dental microwear of sauropod dinosaurs has been analyzed two-dimensionally to detect their diet preferences and niche partitioning. However, it has never been analyzed three-dimensionally using surface texture obtained by a laser microscope, the method called dental microwear texture analysis (DMTA). We inferred the diet of sauropod dinosaurs from the Upper Cretaceous (Turonian) Tamagawa Formation of Kuji Group, northeastern Japan using DMTA. The morphology and age of the Kuji teeth indicates that they belong to a titanosauriform somphospondyli sauropod. Comparison of the Kuji sauropod's dental microwear texture (DMT) to extant lepidosaurs with known dietary preferences showed higher densities of hills and dales in surfaces for the Kuji sauropod. This might indicate a higher degree of oral food processing than in herbivorous lepidosaurs. The DMT of Kuji sauropod was rougher than ovivore lepidosaurs, smoother than molluscivore lepidosaurs, and close to lepidosaurs that fed on plant materials, which is consistent with an herbivorous diet. Considering the paleoflora of the Tamagawa Formation, the Kuji sauropod likely fed on conifers and tree ferns. As this study is the first DMTA on herbivore dinosaurs, there is no comparative sauropod data and the result should be data taken as preliminary. On the other hand, future applications of dental microwear texture analysis to various sauropods could help to reveal the evolution of their feeding ecology and detect niche partitioning among sympatric species.

P28

Interrelationship among dental wear proxies in the extant sika deer with known ecology

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For more than half a century, vertebrate paleontologists and paleoanthropologists have been focusing on the relationship between dietary ecology and dental wear. This has resulted in a substantial number of studies, which clarify or challenge the relationship between tooth wear and diet (and other factors) on varying observational scales: from nano-level *in-vitro* experiments, microscopic wear analyses of both reared and wild animals, to macroscopic wear (e.g., mesowear or dental topology) analyses. However, no study yet has connected microscopic wear to larger observational scales (i.e., dental morphology, wear rate) and the evolutionary outcome. Based on an intensive sampling of extant sika deer with associated quantitative dietary and ecological data, the present study clarifies the effects of microscopic wear on tooth wear rate and tooth morphology. For 15 populations of Japanese sika deer, microscopic wear was quantified by three-dimensional dental microwear texture analysis (DMTA) and molar wear rate was calculated using mandibles with known age-at-death. Macroscopic wear was also quantified by mesowear (ordinal assessment of cusp shape and occlusal relief). Additionally, the unworn height of the lower third molar was measured by micro-X-ray CT scanning, which was employed as a proxy of dental wear on the evolutionary scale. Sika deer that consumed a higher amount of grass were characterized by deeper scars on the enamel, which were represented by large values of height and volume parameters of surface roughness parameters. The deeper microscopic scars resulted in a rapid molar wear rate. The accelerated molar wear rate was positively correlated with more rounded cusps and a flatter mesowear profile. Mesowear, finally, was correlated with the degree of hypsodonty (relative unworn molar height). This study is the first to show a “cascade relationship” connecting the cause and the results, the existence of which has been presumed in the macroevolutionary trend of increasing hypsodonty in ungulates but not been tested until today.

P29

Short and long term dietary analyses as a means of evaluating social relationships in the pre-Colonial Middle Ohio River Valley, USA

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The pre-Colonial sites of Turpin and Guard (1000–1300 CE), located in the Middle Ohio River Valley, USA, represent some of the earliest maize farmers in the region. Archaeological and biological analyses indicate the transition to maize agriculture in the Valley occurred abruptly around 1000 CE, however, the social changes associated with this transition are poorly understood. Previous studies have indicated that diet may be used as a proxy to reconstruct social relationships during periods of emerging complexity, as unequal access to resources is one of the earliest signs of social inequality. This study analyzes dietary continuity in the region and explores what diet reveals regarding social structures.

We analyzed diet through short- and long-term indicators of food consumption. Short-term indicators included Dental Microwear Texture Analysis (DMTA | Turpin, n=9; Guard, n=12), which detects foods consumed in the last weeks or months of a person's life. DMTA explores dental micro-features caused by mechanical properties of food, thereby elucidating dietary nuances. Long term indicators of diet included Occlusal Fingerprint Analysis (OFA | Turpin, n=27; Guard, n=9); OFA studies the cumulative effects of food consumption on teeth and the resulting differences in cusp height and shape. It is particularly useful for distinguishing farmers from hunter-gatherers. Together, DMTA and OFA provide complementary points of view regarding dietary signatures on human teeth. For the current study, there are no significant difference between the two populations. They had similar DMTA and OFA values, suggesting a shared diet. Likewise, we found no significant sub-groups that would indicate disparate social groups. The DMTA/OFA dietary reconstruction indicates the consumption of both agricultural and wild foods. The dietary evidence herein, therefore, points to Turpin and Guard having social structures that include cooperative food sharing of both cultivated and collected resources, which aligns with ethnographic studies of contemporary Native American groups.

P30

Functional Morphology of Hyracoid Dentition

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Hyracoid dentitions have previously been noted for their resemblance to plesiomorphic lophodont cheek teeth of certain ungulates (e. g. rhinos). Examining the masticatory process and dental features of the three extant genera *Procavia*, *Heterohyrax* and *Dendrohyrax* provides insight into their ecology and utility as model taxa. The existence of a buccal cutting edge along the molar-premolar row is a key character for all extant hyracoids. This structure is utilized for the unique hyracoid mode of ingestion through the sides of the mouth. As such, this structure stays functional through all wear stages by the means of continuous self-sharpening. By modelling the hyracoid masticatory cycle using the Occlusal Fingerprint Analyser software it is shown that phase I of the power stroke consists mainly of contact between the buccal cutting edges of upper and lower molars. The orientation and movement of the jaw during the power stroke is found to be very similar, with the main differences resulting from different amounts of wear seen in the genera. The predominantly grazing *Procavia* exhibits extensive wear on the molariform teeth from shortly after eruption, exposing large dentine areas on the lingual portion. This leads to a mastication process dominated by a crushing and grinding function. As a nearly exclusive browser, *Dendrohyrax* shows in contrast only minor wear, making for a mastication process dominated by a cutting and shearing function. *Heterohyrax* shows intermediate characteristics in all respects, pointing to a more generalized feeding behaviour. The previously postulated existence of a strong anterior movement of the lower jaw during phase II of the power stroke is rejected. Such a movement had been suggested based on observations in live animals, but is not possible due to anatomical constraints according to our analysis. Anomalous mesowear-scores of hyracoids previously observed are reconfirmed here and are attributed to the functional emphasis on the buccal cutting edge leading to high cusp sharpness.

P31

The rate of dental wear for the prehistoric hunter-gatherers in Japan

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Dental wear pattern has been investigated in relation to subsistence and/or behavior through comparison of various populations. It has also been used for age estimation by calculating population-specific wear rate, because wear patterns are relatively regular in form and rate within population. The present study examined the rate of molar wear of the Jomon, prehistoric hunter-gatherers in Japan. Specimens from several shell-mound sites during the Middle to Final Jomon period (ca. 5000-2400 BP) were assessed using the traditional system of an ordinal scale as an easily comparable format, and the rate of wear was calculated by dividing the score difference between adjacent molars by the difference in eruption age. Here, we present the data, which provides insight against the conception of "strong wear" among the prehistoric Jomon. For a visual comparison, we have calibrated the most widely cited chart illustrating stages of wear with age produced by Brothwell for the Jomon.

P32

Time-resolved variations of trace elements in dental enamel discriminates between breastfed and formula-fed infants in children with known dietary history

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The introduction of non-human milk into the diet of infants probably occurred in recent human evolution as the domestication of herbivores became established. The adoption of non-human milk in nursing infants' unburdened the mothers from the energetic cost of breastfeeding and undoubtedly produced profound effects on the social and family organization. It is reasonable to assume that the first use in the past of non-human milk in nursing infants was linked to the availability of domesticated herbivores. Whether this practice started with the Neolithic is still unclear and it is currently based on indirect archaeological evidence. In this perspective, the ability to discriminate whether an individual was fed with human milk or not during early infancy is a powerful and innovative tool for investigating the past.

This contribution aims to show how it is possible to detect breastfeeding and formula feeding chemical signals in teeth from contemporary infants through time-resolved variations of trace elemental compositions in dental enamel by LA-ICPMS. Histologically-controlled spatial distributions of Sr/Ca ratio along the enamel-dentine junction of 20 naturally exfoliated deciduous teeth of contemporary infants with a known dietary history allowed the validation of models about Sr incorporation from the diet into the forming enamel.

Results show that it is possible to differentiate between human and non-human milk feeding histories. Moreover, the major dietary events during infancy, like the onset of weaning, are easily detectable as changes in the elemental profile slope. Different teeth from the same individual consistently report the same dietary history and the analysis of profiles along enamel prisms and coeval growth lines (Retzius lines) confirm the validity of the analytical setup.

P33

Hunter-gatherer in transformation: a study of two Terminal Pleistocene - Holocene molars from the South-eastern corner of Sundaland

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Sundaland is a landmass influenced by tectonic and sea-level fluctuations during the Pleistocene. Song Gede (SGD) in Nusa Penida island is a strategic dwelling cave occupied since the Late Pleistocene, located on the south-eastern corner of Sundaland towards Wallacea. This study aims to recognize the history of human occupation and adaptation during the transition of Pleistocene-Holocene in the area based on dental record. This work characterizes two second lower molars by means of comparative morphology (ASUDAS), BL and MD measurements. We test its similarity and differentiation by metric and non-metric statistics analysis in order to put them among prehistoric and recent *Homo sapiens* samples from the western Indonesian archipelago. The result shows SGD (48) and SGD (16) are closed to AMH and Preneolithic population also affiliated to recent Australo-Melanesian. Both molar morphologically indicates Song Gede was inhabited by same population in a long period. SGD (48) dated back from Late Pleistocene (18 Ka BP) was developed hunting-gathering subsistence of terrestrial fauna, i.e. Cervidae, Bovidae, and Suidae. In contrast, SGD (16) from the Mid Holocene (5.373 ± 28 CalBP) shows significant buccolingual reduction, probably indicates a diet change to aquatic sources that stimulates local adaptation and evolution in the insular context. This information gives an overview of human biological adaptation on the edge of Sundaland, across the Wallacea during Terminal Pleistocene to Holocene.

Keywords: Sundaland, terminal Pleistocene, preneolithic, human adaptation, Song Gede, Nusa Penida

P34

Dental wear patterns reveal dietary and environmental history in a Western chimpanzee population from Liberia

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Tooth wear analyses acting at distinct temporal scales can be beneficial in interpreting the dietary ecology of chimpanzees (*Pan troglodytes*) that show a highly diverse dietary composition. Microscopic 3DST (short-term signals), macroscopic OFA, and cusp wear data (long-term signals) of first and second molars are combined to explore the dietary ecology of a historical Liberian chimpanzee population with unknown dietary records. Results are compared with tooth wear and feeding data of the Taï chimpanzee population of Côte d'Ivoire with known dietary records, which is used as a reference data set. The results reveal differences in the short-term 3DST data, which are mainly related to the ingestion of dust-covered foods in the Liberian chimpanzees. This leads to the suggestion that they perished during a dust-laden dry period. The OFA results reveal similar areas and inclinations of phase II facets, which provide evidence about the power stroke phase II during the chewing cycle, suggesting a similar long-term dietary ecology between both populations. However, Liberian chimpanzees have a higher proportion of tip-crushing facets and they were found to wear all their cusps similarly. In contrast in the Taï chimpanzees the lingual and buccal cusps of upper and lower molars, respectively possess an advanced cusp wear compared to the remaining cusps. The tip-crushing wear areas and the general cusp wear patterns of the Liberian chimpanzees both indicate a frequent consumption of harder food items that need to be cracked with their molars, while the absence of these wear characteristics in the Taï chimpanzees confirm observations on their tool use behavior during nut cracking. This combined study opens new options for uncovering details of dietary ecologies in chimpanzees and other living and fossil primates, with microscopic tooth wear addressing short-term changes (e.g. seasonality) and macroscopic tooth wear tracing long-term dietary and environmental history of a single population.

P35

Fossil enamel proteomics: the role of amelogenin peptides in sexing ancient humans and animals

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Sex determination of humans and animals plays a central role in the reconstruction of, e.g., demography, life-styles, ecosystems and cultural practices in the past. Traditionally, sexing was estimated through macroscopic observations and morphometric evaluations of skeletal districts, and determined by genetic analyses. Yet, these methodologies are hindered by e.g. the morpho-chemical preservation of the remains themselves and, as far as ancient DNA is concerned, laboratory costs. Recently, the analysis of tooth enamel proteome allowed to determine the sex of humans and animals in a fast, robust and inexpensive way by means of liquid-chromatography mass spectrometry (LC-MS). In particular, owing to chromosome-specific differences in the amino acid sequences of amelogenin isoforms, namely AMELX and AMELY, it is possible to estimate individual sex by querying ion chromatograms and/or through bioinformatic database searches. Currently, our laboratory routinely employs LC-MS to estimate mammals' sex in (sub)fossil and modern dental specimens. Here we show the limits and the advantages offered by the use of proteomics in sexing ancient teeth in comparison with other methods. In addition, we will present several relevant archeological case studies where enamel proteins revealed their strength in inferring the individual's sex.

P36

Finite Element Analysis of Le Moustier 1 maxillary incisors

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One of the most distinct features of Neanderthal's dentition is certainly the presence of proportionally large anterior teeth compared to the molar crowns, usually not observed in other human groups. More specifically, the incisors displayed an unusual morphology marked by a high degree of labial convexity, and by the presence of lingual marginal ridges (or shovelling) and well-developed lingual tubercles. These features are seen as adaptive responses in dissipating heavy mechanical loads resulting from masticatory and non-masticatory activities. This assumption is based on the heavily worn front teeth found in most adult Neanderthal individuals. The high frequency of enamel chipping, antemortem tooth loss and microfractures of the anterior teeth, have been considered as signals of extensive use of teeth as a third hand, in tearing, holding and shaping a variety of objects.

The aim of this study is to examine if Neanderthal anterior teeth were truly adapted to resist high-magnitude bite forces, by combining computer-based dental wear measurements with kinematic simulations and finite element analysis (FEA). We used the anterior dentition of the Neanderthal specimen of Le Moustier 1 focusing on of the left maxillary central incisor during edge-to-edge biting position. We have created two different biting scenarios, one under normal occlusal loading, estimated to be around 60 N, and one during maximum bite force, with a mechanical load of 294 N. The results show that the largest compressive stress is found on the incisal edge, while tensile stress mostly develops lingually along the marginal ridges. This stress pattern is also reflected at the enamel-dentine junction (EDJ) level, to gradually disappear in the dentine. This suggests that the unique morphology characterising the Neanderthal incisors, such as the lingual tubercle and lingual the marginal ridges help in dissipating

the mechanical stress even during high loading scenarios. Finally, our results confirm the functional importance of the EDJ found in other studies in decreasing tensile stress in the crown.

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Rates of dental shape changes with age in African rainforest hunter-gatherers

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The Baka Pygmy populations inhabit rainforests in south-eastern Cameroon. Despite documented changes in mobility patterns between small-scale farming settlements and forest camp-life, the subsistence economy among Baka Pygmies still relies on hunting and wild plant-food gathering. Wear of teeth is a physiological age-dependent process determined by dietary abrasiveness. Studies conducted on hunter-gatherers suggest that mechanical food properties differently impact on occlusal morphology as the enamel wear. However, little is known about the age-related tooth crown shape changes from living hunter-gatherers according to well-documented foraging activities. High-resolution non-translucent polyurethane replicas of the full-occluded first mandibular permanent molars (M1s) were produced from polyvinyl siloxane-based molds obtained from Baka individual dentitions (47 females, 29 males) aged from 11 to 31 years in the village of Moango-le-Bosquet (Lomié District, Cameroon). Three-dimensional (3D) models of M1s were generated using a structured-light 3D scanner. Meshes were post-processed to collect topographic metrics including occlusal surface sharpness (angularity), relative crown height (occlusal relief) and changes in elevation (slope) using the R package doolkit. We found strong relationships between topographic metrics and age for both Baka female and male individuals. It is noteworthy that analysis of covariance revealed significant sexual dimorphic trends in occlusal relief and slope with aging. The female molars are characterized by significantly reduction in cusp slopes and heights than those of male individuals who show steeper slopes and relatively taller crowns as wear accrue, probably associated with differences in abrasiveness of long-term chewed specific food-types. Our findings denote that diet-related masticatory biomechanics largely impact on the dynamics of tooth-shape changes with age and provide new insights about sex-related dental functional demands among hunter-gatherer populations.

Keywords: dental topography; age changes; diet; African foragers

P38

How is the occlusal morphology established in human molars?

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Correctly-shaped teeth are crucial for most mammals. The occlusal morphology of the tooth is initially determined during the patterning stage and is then finalized with the secretion of the enamel matrix layer. In our previous work (Häkkinen et al. 2019), we studied the species-specific enamel distribution in suid and primate molars. Based on the topographic analyses, we presented a computational model that simulates the secretion of enamel matrix in 2D. Our model successfully reproduces the enamel distribution of domestic pig, human and orangutan molars, indicating that the diffusion of nutrients during the enamel matrix secretion could be a key factor driving the species-specific distribution of enamel.

In the current work, we study the variation in enamel distribution in human molars. The morphology of human molars can vary in the overall shape of the crown, the number of cusps, and in the wrinkling of the occlusal basin. Our aim is to test if the variation of the occlusal basin can be explained only by the morphology of the enamel-dentine junction (EDJ), or if it is affected by other factors, such as nutrient-limited secretion of enamel matrix. To do this, we analyse the occlusal morphologies of third molars. In humans, as in many other mammals, the morphology of the third molar varies the most which makes it ideal to analyse the variation in the EDJ and enamel distribution. Additionally, we studied molars of a child with rickets. Rickets is a disease caused by lack of vitamin D. Vitamin D regulates the balance of calcium and phosphate, two essential elements of mineralised tissues, including tooth enamel. Enamel of rickety teeth is often thin. Using computational simulations and topographic analyses, we show how the nutrient-limited matrix secretion can account for normal and abnormal variation in the enamel distribution in human molars.

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A case of impacted third molar from the prehistoric hypogeum of Calaforno (Sicily): reflections on the antiquity and evolutionary implications of this ancestral trait

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This contribution examines a fragmented right mandibular hemiarch found in the Hypogeum of Calaforno (Ragusa), a very important prehistoric Sicilian funerary site consisting of 35 chambers inside which several commingled remains were retrieved. The hemiarch, found in Chamber 30, is broken in correspondence of the second premolar and the mandibular ramus, with the first and second molars still *in situ*. The matching left mandibular hemiarch was also found showing that the contralateral alveolar socket hosted an erupted third molar.

The investigated mandibular fragment was subjected to X-ray examination (X-ray in latero-lateral projection) and CT scan, revealing the presence of the third molar completely included in the alveolar process in a horizontal position, whose crown presses onto the root of the second molar. Such a finding is entirely accidental. Based on the left third molar age at death of the individual to whom the mandibular fragment belonged was estimated using the AlQahtani method (2008), while sex was determined based on the morphology of the mandible adopting the Ferembach et al. method (1979).

In a contemporary living patient, this condition can be found to be asymptomatic, while it can also prove very painful, as the third molar compresses the root of the second molar with its nerve endings, as in the case described here. The cause of this morphology may be genetic.

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