# 17th International Symposium on Dental Morphology

## &

# 2nd congress of International Association for Paleodontology



**4-7 October 2017**

**BORDEAUX│France**

# CONTENT

# WELCOME LETTER

The research unit PACEA (Unité Mixte de Recherche 5199) is delighted to host the 17th International Symposium on Dental Morphology (ISDM) and 2nd congress of the International Association for Paleodontology (IAPO) at the University of Bordeaux, France, from 4-7 October, 2017. We are happy to welcome you at the domaine du Haut-Carré in Talence, a former convent converted in a research conference venue and the official home of the President of the University of Bordeaux.

ISDM-IAPO is an interdisciplinary symposium, bringing together researchers in anatomy, palaeoanthropology, palaeontology, archaeology, dentistry, genetics, biology and biomechanics, focussing on various themes: dental evolutionary changes, teeth in archaeology, dental growth and development, biomechanical aspects of the masticatory apparatus, odontology, pathology and oral health in present and past populations, evo-devo of hard tissues and new methods in dental studies.

This meeting takes place every three years and PACEA hosts the symposium after very successful meetings in Greifswald (2008), Newcastle upon Tyne (2011) and Zagreb (2014). More than 50 years after the first meeting in Fredensborg, Denmark, in 1965, the symposium has become a very prominent event, as shown by the high number of high quality abstracts that we received this year.

The scientific board includes members of PACEA and other French research units (UMR 5188 AMIS at Toulouse, UMR 5242 IGFL at Lyon, UMR 5554 ISEM at Montpellier, UMR 7179, 7207 et 7209 at the Natural History Museum in Paris, UMR 7264 CEPAM at Nice), as well as international colleagues from University College London, British Museum, Natural History Museum and Queen Mary University in London, Universitat Rovira i Virgili in Tarragona, University of Michigan, University of Bristol, University of Kent, Max Planck Institute for Evolutionary Anthropology in Leipzig, University of Zagreb and University of Oulu.

The scientific program is organized around eight sessions: Dental evolution in deep time, Teeth and archaeology (humans & animals), Dental growth and development, Dental function and biomechanics, Odontology and Paleodontology, Tooth evo-devo, Genetics and epigenetics as well as New methods in dental studies. The final day is dedicated to an excursion to the *Vallée de l'Homme* in Dordogne.

We warmly thank you for taking part in making this meeting a success, and we look forward to seeing you all at the next symposium in 2020.

All best wishes,

Priscilla Bayle and Christopher Dean

On behalf of the organizing and scientific boards

# ORGANIZING BOARD

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# PROGRAMME

**17h30-19h30: Guided tour of Bordeaux│Assembly point at Place de la Comédie in front of Bordeaux Grand Théâtre**

**8h00-9h00: Meeting registration│Main entrance Haut-Carré (tram B stop "Forum")**

**9h00-9h30: Opening speech by Anne Delagnes (Head of UMR5199 PACEA), Christopher Dean (President of the scientific board) & Priscilla Bayle (President of the organizing board)│Agora**

**9h30-10h30: Podium session 8. New methods in dental studies│Agora**

**Chair and discussant: Marie Balasse (Muséum national d'Histoire naturelle Paris, France)**

9h30-9h45: <u>Daniela E. Winkler</u> & Thomas Tütken│A combined dental wear and isotope approach for dietary reconstruction in extant and extinct reptiles with a focus on *Crocodilia*

9h45-10h00: <u>Léonie Rey</u>, Théo Tacail, Vincent Balter, Stéphane Rottier & Gwenaëlle Goude│Tracking dietary changes and mobility patterns at a near weekly scale during childhood by LA-ICP-MS analysis in dental enamel: an experimental study on a Neolithic population in the Paris Basin (France)

10h00-10h15: <u>Louise Humphrey</u>, Brenna Hassett, Ali Freyne & Christopher Dean│Micro-spatial patterning of lead and zinc in deciduous tooth enamel

10h15-10h30: <u>Stuart Stock</u>, Stephan Naji, William Rendu, Lionel Gourichon & Zhonghou Cai│Simultaneous x-ray excited x-ray fluorescence and x-ray diffraction quantitative mapping of annual bands in cementum using sub-micrometer beams of synchrotron radiation

**10h30-11h00: Coffee break│Salle Badiane**

**11h00-12h00: Podium session 8. New methods in dental studies│Agora**

**Chair and discussant: Jukka Jernvall (University of Helsinky, Finland)**

11h00-11h15: Mia Tomaic, Luka Cular, Tea Saric, Viktorija Sajkovic, Ivan Galic, Marko Subasic & <u>Marin Vodanovic</u>│Application of artificial intelligence in dental age estimation

11h15-11h30: <u>Elis Newham</u>, Kate Robson Brown, Pamela Gill & Ian Corfe│Sexual dimorphism in primate dental cementum microstructure

11h30-11h45: <u>G. Richard Scott</u>, David Navega, Marin Pilloud, João Coelho, Eugénia Cunha & Joël Irish│Estimating Ancestry from Dental Morphology: The Development and Testing of rASUDAS

11h45-12h00: <u>Clément Zanolli</u> & Roberto Macchiarelli│A "diphyodontic conundrum": do the enamel and dentine of the deciduous and permanent molars tell a similar story?

**12h00-13h15: Podium session 4. Dental function and biomechanics│Agora**

**Chair and discussant: William L. Hylander (Duke University, UK)**

12h00-12h15: <u>Alireza Omidi</u>, Mohammad Ali Nazari & Christophe Jeannin│The effect of TMJ prosthesis on jaw's kinematical characteristics including muscle forces

12h15-12h30: <u>Julia Stuhlträger</u>, Ellen Schulz-Kornas, Roman Wittig, Ottmar Kullmer & Kornelius Kupczik│ Seasonality and population specific tooth wear in forest-dwelling Western Chimpanzees (*Pan troglodytes verus*)

12h30-12h45: <u>Ulrike Menz</u> & Ottmar Kullmer│Adaptive phase II elongation from fossil to modern apes

12h45-13h00: <u>John Kaidonis</u> & Grant Townsend│Dental microwear: teasing out the complexities

13h00-13h15: <u>Rachel Sarig</u>, Ariel Pokhojaev, Ellen Schulz-Kornas & Nir Shvalb│Understanding the interproximal dental wear mechanism using 3D surface texture analysis

**13h15-14h15: Lunch break│Salle Badiane**

**14h15-15h15: Podium session 1. Dental evolution in deep time│Agora**

**Chair and discussant: B. Holly Smith (University of Michigan, USA)**

14h15-14h30: <u>Guillaume Billet</u> & Jérémie Bardin│Serial homology, correlated evolution and phylogenetic signal in molars of placental mammals

14h30-14h45: <u>Helder Gomes Rodrigues</u>, Raphaël Cornette, Anthony Herrel & Guillaume Billet│Dental convergences and morphological diversity of the masticatory apparatus in extinct ungulate mammals

14h45-15h00: <u>Carolina Loch</u>, Jules Kieser & R. Ewan Fordyce│On the evolution (and devolution) of whale and dolphin enamel

15h00-15h15: <u>Antoine Souron</u>, Gildas Merceron & Jean-Renaud Boisserie│ Adaptive dental evolution in African suids: insights from new Plio-Pleistocene samples of *Kolpochoerus* from the Shungura Formation (Lower Omo Valley, Ethiopia)

2.1. <u>Linda Elisabete Melo</u>, Carlos Emanuel Ferreira, Luís Miguel Marado & Ana Maria Silva│Dental restoration in past populations: A study case from Travanca's Church Cemetery (Santa Maria da Feira, Portugal)

2.2. <u>Carlotta Sisalli</u>, Piera Allegra Rasia, Roberto Cameriere, Fiorella Bestetti, Sauro Gelichi & Francesca Bertoldi│Analysis of dental pathologies and stress indicators in a human sample from the Medieval cemetery of Jesolo Le Mure-Venice, Italy

7.1. <u>Jelena Dumančić</u>, Zvonimir Kaić, Hrvoje Brkić & Miroslav Dumić│Premolar and molar root morphology in X chromosome aneuploidy

2.3. <u>Luís Miguel Marado</u>│Dental fluctuating asymmetry in Portugal: Developmental instability in Valença and the Coimbra reference sample

2.4. <u>Ricardo Ortega-Ruiz</u>, Juan Pablo Diéguez Ramírez, Daniel Botella Ortega & Elena García López de la Franca│Dental health in Late Antiquity: Comparison between the sites of Cortijo Nuevo and Cortijo Coracho Lucena, Córdoba, España

2.5. <u>Valentina Giacometti</u>, Francesca Bertoldi, Daniela Cottica, Roberto Cameriere & Francesco Pagliara│An evaluation of the oral health of a Late Antiquity human sample from Piazza Corrubbio-Verona, Italy

2.6. <u>Consuelo Rodriguez</u>, Clizia Murgia, Diego López-Onaindia, Francesca Biscu, Ilenia Atzori, Vittorio Mazzarello & Maria Eulàlia Subirà│Demographic and paleopathological study from Sardinian dental remains

2.7. <u>Stephan Naji</u>, William Berthon, Leslie Quade, Antony Colombo, Olivier Dutour & Christophe Saint-Pierre│Teeth, paleodemography and paleopathology: a cementochronology analysis of the Medieval site of La Granède, France

2.8. <u>Samantha Field</u>│Comparing the rates of dental wear of two archaeological populations and their implications to Brothwell's method

7.2. <u>Claire Willmann</u>, Xavier Mata, Laure Tonasso, Lenka Tisseyre, Céline Jeziorski, Elodie Cabot, Pierre Chevet, Eric Crubézy, Rémi Esclassan & Catherine Thèves│Oral diseases in historical populations

2.9. <u>William Rendu</u>, Stephan Naji, Eric Pubert, Carlos Sánchez-Hernández, Manon Vuillien, Hala Alarashi, Emmanuel Discamps, Elodie-Laure Jimenez, Solange Rigaud & Lionel Gourichon│Cementochronological analysis in zooarchaeology: a new analytical protocol

2.10. <u>Elodie-Laure Jimenez</u>│Gangs with fangs: Contribution of cementum analysis towards the understanding of human and hyaena seasonal settlements in Belgium during the Late Pleistocene

2.11. <u>Manon Le Neün</u>, Thomas Cucchi, Elise Dufour & Nicolas Goepfert│Geometric morphometrics of molar teeth of South American Camelids: an exploratory approach for taxonomic identification of modern and archaeological individuals

2.12. <u>Alexandra Ibrová</u>, Sylva Kaupová, Priscilla Bayle, Petr Velemínsky, Lumír Poláček & Jana Velemínská│Diet of the early Medieval elites (Great Moravian Empire, 9th – 10th century AD, Czech Republic): Synthesis of geochemical methods and virtual anthropology

2.13. <u>G. Richard Scott</u>, Simon Poulson, Kirk Schmitz & Amanda Harvey│Estimating stable Carbon and Nitrogen isotope compositions from dental calculus: from serendipity to synthesis

2.14. Sélim Natahi, Mona Le Luyer, Priscilla Bayle, Grégory Pereira, Véronique Darras & Brigitte Faugère│Assessing human settlement dynamics in West-Central Mesoamerica through dental morphological and metrical variation: preliminary results

2.15. Tatiana Vlemincq Mendieta│The muddle in the middle? Characterizing population diversity in Coastal Central Peru in the Prehispanic Period, using dental non-metric traits

2.16. Iztok Štamfelj & Tomaž Hitij│Dentition of the Hun warrior from Ptuj (Slovenia)

2.17. Arwa Kharobi & Caroline Polet│Show me your teeth: dental anthropology as evidence for biological affinities and cultural practices in Urkesh (Syria) during the Middle Bronze Age

2.18. Ana Maria Silva & Rui Boaventura│Tooth wear and evidence of non-masticatory dental use in Late Neolithic Age individuals exhumed from the artificial cave of Baútas (Lisbon, Portugal)

2.19. Susana Gómez-González, Laura González-Garrido, Sofia Wasterlain, Consuelo Roca de Togores Muñoz & Jorge A. Soler Díaz│Non-masticatory dental wear of anterior teeth in Late Neolithic individuals from Alicante (Spain) burial caves and rock shelters

2.20. Iris Herscu, Yankel Gabet & Rachel Sarig│Dental morphological changes in the Levant populations during the Holocene

2.21. Solange Rigaud│Exploring past exchange networks and symbolic hunting through the study of mammal teeth beads

2.22. Diego López-Onaindia, Marina Lozano, Alvaro Arrizabalaga & Maria Eulàlia Subirà│New insights into the Mousterian Human teeth from Lezetxiki cave (Arrasate, Basque Country)

2.23. Hélène Rougier & Priscilla Bayle│A previously unnoticed Neandertal dental autapomorphy?

7.3. Vilma Väänänen, Mona Christensen, Heikki Suhonen & Jukka Jernvall│X-ray microtomography as a tool for imaging gene expression and tissue morphology in developing tooth

7.4. Mathilde Hourset, Carine Froment, Clément Zanolli, Nancy Saenz, Claire Willmann, Emmanuelle Mouton-Barbosa, Rémi Esclassan, Catherine Thèves, Odile Burlet-Schiltz & Catherine Mollereau-Manaute│Ancient tooth proteomes

## 17h15-18h15: Podium session 1. Dental evolution in deep time│Agora

**Chair and discussant: Bernard Wood (George Washington University, USA)**

17h15-17h30: Chrisandra Kufeldt, Wendy Dirks & Bernard Wood│Ancestral state reconstructions of dental development in Miocene fossil taxa

17h30-17h45: Florian Martin, Chris Plastiras, Gildas Merceron, Antoine Souron, Jean-Renaud Boisserie│Feeding habits of terrestrial monkeys track paleoenvironmental conditions in Omo Valley, Plio-pleistocene of Ethiopia

17h45-18h00: Matthew Skinner, Paul Klassen, Zeresenay Alemseged, Bernard Wood & Jean-Jacques Hublin│Patterns of metameric variation in premolar root morphology in fossil hominins

18h00-18h15: Annabelle Lockey, María Martinón-Torres, Laura Martín-Francés, Juan Luis Arsuaga & José María Bermúdez de Castro│Application of micro tomography to the mandibular incisors of Sima de los Huesos

### La grotte ornée et sépulcrale de Cussac (Dordogne)

La grotte de Cussac (Dordogne, SW France) est originale à plusieurs titres : un art gravé exceptionnel, parfois monumental, des restes humains déposés dans des bauges d'ours et un niveau de préservation et de conservation des sols ou des parois remarquable. La cavité fait l'objet d'importants travaux pluridisciplinaires engageant une cinquantaine de chercheurs depuis 2009. La fréquentation du site remonte à une période appelée Gravettien, soit vers 28-29 000 ans avant le présent, soit à mi-chemin entre Chauvet et Lascaux. Sa découverte en 2000 a ouvert de nouvelles perspectives quant à la fonction des grottes ornées associant désormais le dépôt de corps dans la proximité de parois gravées. Nous présenterons un panorama général de ce patrimoine et des recherches qui s'y déroulent.

### The decorated and sepulchral cave of Cussac (Dordogne)

Cussac cave (Dordogne, SW France) is original in many respects: exceptional, sometimes monumental, engraved art, human remains associated with bear hollows and a remarkable preservation of grounds or walls. The site's occupation goes back to a period called the Gravettian and is dated to approximately 28-29 000 BP, in other words: halfway between Chauvet and Lascaux. Its discovery in 2000 has opened up new perspectives regarding the function of decorated caves that are now known to show bodies deposited next to engraved walls. Since 2009, the cave is the object of important multidisciplinary studies involving about fifty researchers. Here we shall present an overview of this site and the research that has taken place over the last eight years.
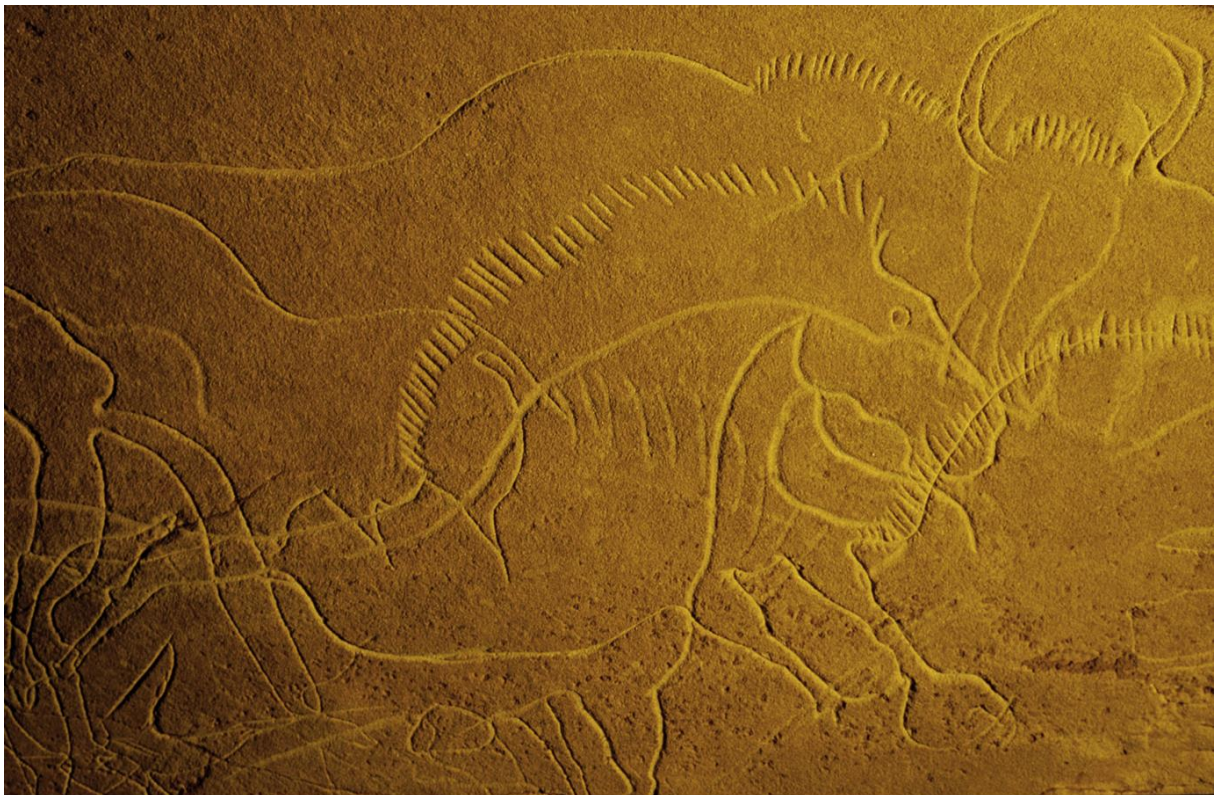


*Cussac Cave (Dordogne, France): Grand panel (Photo N. Aujoulat / MCC-CNP / PCR Cussac).*

**9h00-9h30: Keynote speech by Grant Townsend (University of Adelaide, Australia)│Agora**

**Genetic and epigenetic influences on teeth, faces and oral health of twins: 35 years of research**

See abstract page 158.

**9h30-10h15: Podium session 2. Teeth and archaeology (humans and animals)│Agora**

**Chair and discussant: Gildas Merceron (University of Poitiers, France)**

9h30-9h45: Thomas Cucchi, Azadeh Mohaseb, Stéphane Peigné, Ludovic Orlando & Marjan Mashkour│Detecting taxonomic and phylogenetic signals in equid cheek teeth: towards new palaeontological and archaeological proxies

9h45-10h00: Marie Balasse, Juliette Knockaert, Henri Gandois & Denis Fiorillo│Sheep birth distribution in past herds from oxygen isotope analysis in teeth: a review for prehistoric Europe (6th – 3rd millennia BC) and the comparative use of upper and lower molars for this purpose

10h00-10h15: Florent Rivals, Keiko Kitagawa, Julien Marie-Anne, Marylène Patou-Mathis, Alexander A. Bessudnov & Alexander N. Bessudnov│Dental micro- and mesowear as high-resolution proxies for the study of ungulate diet and its relation to the human occupation patterns at Divnogor'ye 9 (Late Pleistocene, Russia)

**10h15-10h45: Coffee break│Salle Badiane**

**10h45-12h30: Podium session 6. Tooth evo-devo│Agora**

**Chair and discussant: Nicolas Goudemand (Ecole Normale Supérieure Lyon, France)**

10h45-11h00: Mélanie Debiais-Thibaud & Véronique Borday-Birraux│Tooth and scale morphogenesis in shark: an alternative process to the mammalian enamel knot system

11h00-11h15: Lionel Hautier & Sérgio Ferreira Cardoso│A developmental perspective on the evolution of the dentition of "toothless mammals"

11h15-11h30: Jukka Jernvall, Mia Valtonen & Yoland Savriama│The outer limits of developmental conservation of mammalian tooth shape

11h30-11h45: Ludivine Bertonnier-Brouty, Laurent Viriot & Cyril Charles│Ontogenetic modifications of dental shape recapitulate ancestral tooth character states in Lagomorpha

11h45-12h00: Ian Corfe, Aki Kallonen, Jaqueline Moustakas, Heikki Suhonen, Jukka Jernvall & Keijo Hämäläinen│Connecting prisms and tubules: the 3D relationships of enamel spindles revealed by nanometer scale synchrotron imaging

12h00-12h15: Cyril Charles, Kerstin Seidel, Pauline Marangoni, Ludivine Bertonnier-Brouty, Mathilde Bouchet, Laurent Viriot & Ophir Klein│Reactivation of evolutionary lost molar replacement in mice

12h15-12h30: <u>Alejandra Ortiz</u>, Shara Bailey, Gary Schwartz, Jean-Jacques Hublin & Matthew Skinner│Does the Patterning Cascade Model explain accessory cusp variation in the hominoid clade?

**12h30-14h00: Lunch break│Salle Badiane**

**14h00-15h15: Podium session 2. Teeth and archaeology (humans and animals)│Agora**

**Chair and discussant: Simon Hillson (University College London, UK)**

14h00-14h15: <u>Michael Rivera</u> & Jay Stock│What teeth can tell us about agricultural transitions on the coast: a case study from the prehistoric Baltics

14h15-14h30: <u>Zuriñe Sánchez-Puente</u>, Rebeca García-González, Yuliet Quintino, Laura Rodríguez, Amalia Pérez-Romero, Eneko Iriarte, Juan Luis Arsuaga & José Miguel Carretero-Díaz│Dietary inferences of the Chalcolithic population from El Portalón de Cueva Mayor (Sierra de Atapuerca, Burgos)

14h30-14h45: <u>Carsten Witzel</u>, Horst Kierdorf, Uwe Kierdorf & Arkadiusz Soltysiak│Complex type enamel hypoplasia in human permanent canines from a mass fatality in an early urban center in Syria

14h45-15h00: <u>Christianne Fernee</u>, Kate Robson Brown & Sonia Zakrzewski│All shapes and sizes: variation of tooth form between and within historic populations from Southern Britain

15h00-15h15: <u>Rebecca Whiting</u>, Simon Hillson & Daniel Antoine│Periodontal disease, aetiology, biological processes and its connection to diet and dietary consistency: a case study from Medieval Sudan

**15h15-15h45: Coffee break│salle Badiane**

**15h45-16h45: Podium session 2. Teeth and archaeology (humans and animals)│Agora**

**Chair and discussant: Matthew Skinner (University of Kent, UK)**

15h45-16h00: <u>William Rendu</u>, Eric Pubert, Emmanuel Discamps & Lionel Gourichon│Neanderthal hunting seasonality and mobility patterns: a cementochronological approach

16h00-16h15: <u>Kate Robson Brown</u>, Elis Newham, Priscilla Bayle, Iwan Jerjen, Heidi Dawson-Hobbis, Ian Corfe & Pamela Gill│Sexual dimorphism in dental cementum microstructure: applications for sexing in archaeological modern human and Neanderthal remains

16h15-16h30: <u>Lionel Gourichon</u>, Eric Pubert & William Rendu│Seasonality studies using dental cementum analysis of ungulate hypsodont teeth: issues and perspectives

16h30-16h45: <u>Carlos Sánchez-Hernández</u>, Ramón Montes-Barquín, Ruth Blasco, Jordi Rosell, William Rendu, Lionel Gourichon & Florent Rivals│An innovative approach to Neanderthal occupational patterns by integrating dental wear and cementochronology. Case studies of Cova de les Teixoneres and Cueva de Covalejos (Iberian Peninsula)

**16h45-20h00: Poster session 3. Dental growth and development & 4. Dental function and biomechanics│Cloître & Drinks│salle Badiane**

3.1. Kateřina Pospíšilová, <u>Alizé Lacoste Jeanson</u> & Jaroslav Brůžek│Social differences and the onset of puberty: study from teeth mineralization in two populations of the Great Moravia (9-11th centuries, Czech Republic)

3.2. <u>Andrew Fulton</u> & Helen Liversidge│A radiographic study of root resorption of mandibular deciduous molars

3.3. <u>Priscilla Bayle</u>, Caroline Damiano, Mona Le Luyer, Arnaud Mazurier & Anne-marie Tillier│Dental developmental pattern and tooth internal structure in the Neanderthal child Châteauneuf 2 (Hauteroche, Charente, France)

3.4. <u>Wendy Dirks</u>, Brett Nachman & Robert Anemone│New data on developmental sequences in the dentitions of the Euarchonta

3.5. <u>Shannon McFarlin</u>, Donald Reid, Meagan Vakiener, Keely Arbenz-Smith, Michael Cranfield, Tara Stoinski, Antoine Mudakikwa & Timothy Bromage│Comparison of histological and radiographic assessments of molar development in Virunga mountain gorillas from Rwanda

3.6. <u>Emmy Bocaege</u>, Horst Kierdorf, Uwe Kierdorf & Carsten Witzel│Incremental enamel growth of Natufian deciduous teeth from Shubayqa, Jordan

3.7. <u>Rosie Pitfield</u> & Patrick Mahoney│Variation in human prenatal enamel formation rates of permanent first molars

3.8. <u>Brenna Hassett</u>, Louise Humphrey & Christopher Dean│Appearance of the neonatal line depends on gestational rather than delivery variables

3.9. <u>Mona Le Luyer</u> & Patrick Mahoney│Biorhythm in deciduous molars from the Tooth Fairy collection: preliminary results

3.10.<u>Susanna Sova</u>, Teemu Häkkinen, Heikki Suhonen & Jukka Jernvall│Mineralization front in enamel of pig molar studied using microCT and modeling

3.11.<u>Patricia Kahle</u>, Carsten Witzel, Uwe Kierdorf, Kai Frölich & Horst Kierdorf│Mineral apposition rates in coronal dentin of mandibular first molars of Soay sheep - results of a fluorochrome labeling study

4.1. <u>Tilen Šušterčič</u>, Taja Pogorelčnik & Iztok Štamfelj│Hardness of the root dentine: a comparative study of human primary and permanent mandibular incisors

4.2. <u>Vincent Lazzari</u>, Ghislain Thiery & Franck Guy│Quantification of the involvement of enamel thickness variations in production and modification of occlusal dental traits in Primates

4.3. <u>Jeremy Tausch</u>, Timothy Bromage & Ottmar Kullmer│A new method for determining the 3D spatial orientation of molar microwear

4.4. <u>Gildas Merceron</u>, Anusha Ramdarshan, Cécile Blondel, Jean-Renaud Boisserie, Noël Brunetiere, Arthur Francisco, Denis Gautier, Xavier Milhet, Alice Novello, Dimitri Pret & Jérôme Surault│Food, dust and tooth wear: a sheep perspective

4.5. <u>Marlon Bas</u>, Mona Le Luyer & Priscilla Bayle│Exploratory study of microwear signatures in human deciduous molars from the Tooth Fairy collection, methodological considerations

4.6. <u>Emilie Berlioz</u>, Dimitris Kostopoulos, Cécile Blondel & Gildas Merceron│Exploring the dietary plasticity of *Eucladoceros ctenoides*: what does its occurrence in the fossil record mean?

4.7. <u>Gregorio Oxilia</u>, Ottmar Kullmer, Grant Townsend, John Kaidonis, Jacopo Moggi-Cecchi, Luca Fiorenza & Stefano Benazzi│Asymmetry, balance and dental macrowear patterns of Yuendumu Aboriginals: a case study

4.8.  Almudena Estalrrich, Antonio Rosas & Ottmar Kullmer│Molar macrowear variability within the Neandertals from El Sidrón (Spain)

4.9.  Franck Guy, Ghislain Thiery & Vincent Lazzari│3D quantification of the occlusal enamel curvature: a decisive feature in dental function analysis and diet in Primates

4.10. Luca Fiorenza│Functional tooth wear inclination in great ape molars

4.11. Michael Berthaume, Kornelius Kupczik & Lucas Delezene│Ecological differentiation in *Homo naledi*

4.12. Ghislain Thiery, Vincent Lazzari, Gildas Merceron & Franck Guy│Putting 3D dental topography into practice: the dental tools of a Pliocene colobine monkey, *Dolichopithecus ruscinensis*

4.13. Viviana Toro-Ibacache, Francisco Ugarte, Jose Aguilera & Williams Astudillo│Variation of the human mandible shape is a matter of allometry and secondarily, of diet

4.14. Irina Reshetova│The criterion of temporomandibular joint wear in determining biological age

4.15. Liliana Carvalho & Sofia Wasterlain│A palimpsest of diseases: the relation of temporomandibular joint osteoarthritis with *ante mortem* tooth loss in a medieval sample from Coimbra, Portugal

4.16. Catharina Ludolphy, Patricia Kahle, Horst Kierdorf & Uwe Kierdorf│Temporomandibular joint pathology in Eastern Atlantic harbour seals (*Phoca vitulina vitulina*) from the German Wadden Sea

4.17. Julián Balanta-Melo, Maria Torres-Quintana, Viviana Toro-Ibacache, Kornelius Kupczik & Sonja Buvinic│Bone microstructure and gene expression in the mouse mandibular head after botulinum toxin-induced masseter muscle paralysis

4.18. Alexandra Schuh, Kornelius Kupczik & Sarah Freidline│The relationship between maxillary bone development and dental eruption in humans: a study using microscopy and geometric morphometric techniques

## FRIDAY, 6 OCTOBER

**9h00-10h15: Podium session 3. Dental growth and development│Agora**

**Chair and discussant: Tanya Smith (Griffith University, Australia)**

9h00-9h15: Simon Hillson│Patterns of correlation in growth as measured by tooth crown height and bone dimensions in a large assemblage of children's skeletons from an ancient cemetery on the island of Astypalaia in Greece

9h15-9h30: B. Holly Smith│Tooth emergence as a significant event in life history

9h30-9h45: Alan Mann & Janet Monge│Dental Evidence for Middle Childhood

9h45-10h00: Helen Liversidge & Theya Molleson│A study on early development of permanent incisors and canines

10h00-10h15: Caroline Partiot, Bruno Maureille, Emmy Bocaege, Ronan Ledevin, Mark Guillon & Dominique Castex│Undocumented anatomical trait common to Neandertal and Extant Human on the upper deciduous incisor crown of individuals in perinatal period: anatomical description and micro-CT study

**10h15-10h45: Coffee break│salle Badiane**

**10h45-12h00: Podium session 3. Dental growth and development│Agora**

**Chair and discussant: Luca Bondioli (National Museum of Prehistory and Ethnography "Luigi Pigorini", Italy)**

10h45-11h00: Tanya Smith, Julia Boughner, Quentin Greba, John Howland & Amanda Papakyrikos│Experimental manipulations of biological rhythms in mammalian teeth

11h00-11h15: Horst Kierdorf, Carsten Witzel, Friederike Breuer, Anna Kellner & Uwe Kierdorf│Incremental markings in porcine enamel revisited – evidence for a daily periodicity of laminations in wild boar teeth

11h15-11h30: Simone Lemmers, Wendy Dirks, Barthelemy Ngoubangoye, Anais Herbert & Joanna Setchell│Stress, dental development, and life history in mandrills (*Mandrillus sphinx*)

11h30-11h45: Kate McGrath, Donald Reid, Keely Arbenz-Smith, Michael Cranfield, Tara Stoinski, Timothy Bromage, Antoine Mudakikwa & Shannon McFarlin│LEH defects and accentuated striae: Do they co-occur in great ape canines?

11h45-12h00: Alessia Nava, Alfredo Coppa, Christopher Dean, Lucia Mancini, Diego Dreossi & Luca Bondioli│How was your mother? Inferring human fetal growth patterns and maternal health from the prenatal enamel microstructure

**12h00-14h45: Poster session 1. Dental evolution in deep time, 5. Odontology and paleodontology 6. Tooth evo-devo & 8. New methods in dental studies│Cloître & Lunch break│Salle Badiane**

5.1. Ana Solari, Rodrigo Oliveira, Sergio Monteiro da Silva, Gabriela Martin & Anne Marie Pessis│A case of dental erosion in an subadult individual exhumed at Pedra do Cachorro archaeological site (Pernambuco, Brazil) during the Late Holocene

5.2. Irene Dori & Jacopo Moggi-Cecchi│Further evidence of an unusual dental enamel alteration in prehistoric Italian populations

5.3. Toetik Koesbardiati & Delta Murti│Enamel hypoplasia in Melolo prehistoric people Indonesia

5.4. Elsa Garot, Christine Couture-Veschambre & Patrick Rouas│First cases of enamel hypomineralisation amongst past populations: a new approach in understanding MIH etiologies

5.5. Janet Davies, Ferranti Wong & Graham Davis│Hypomineralised Amelogenesis Imperfecta – an X-ray microtomographic study

5.6. Elena Cedarry, Elsa Garot, Patrick Rouas, Benat Lascano & Frederic Bauduer│Basques demonstrate a high prevalence of molar-incisor hypomineralisation (MIH)

5.7. Uwe Kierdorf, Morten Tange Olsen, Catharina Ludolphy, Patricia Kahle & Horst Kierdorf│Periapical abscesses and suppurative osteomyelitis of the jaws due to failure of dentin formation in Baltic grey seals (*Halichoerus grypus grypus*) from the 19th century

5.8. Lucija Strmšek & Iztok Štamfelj│The prevalence of three-rooted permanent mandibular molars in a Slovenian population

5.9. Tomaž Hitij, Luka Hocevar & Iztok Štamfelj│Bilateral presence of Radix Entomolaris in first and second permanent mandibular molars identified in a Caucasian woman: A case report

5.10. Christophe Bou, Marie Audrey Say Liang Fat, Ronan Ledevin, Larbi Benali & Karine Levet│Dens Invaginatus: A virtual analysis

5.11. Anne-marie Tillier, Hélène Coqueugniot, Bruno Dutailly, Olivier Dutour, Gyorgy Pal & Ildiko Pap│Dental development of the Neanderthal child from Subalyuk (Hungary). Anomalies of tooth shape and dental arch relationship

5.12. Ivana Savić Pavičin, Nataša Ivošević-Magdalenić, Ana Kotarac Knežević & Leona Keretić│Oligodontia: Congenitally missing of eight permanent teeth – A case report

5.13. Shota Kataoka, Masanori Iwasaki, Satoko Kakuta, Inho Soh & Toshihiro Ansai│Consideration of tooth loss in ancient Japanese

5.14. Jessica Gross & Heather Edgar│Estimating ancestry proportions in African American samples using dental morphology

5.15. Jaana Sverloff, Tuomo Heikkinen & Pentti Kirveskari│Dental traits of Skolt Sámi

5.16. Cecilia García-Campos, María Martinón-Torres, Laura Martín-Francés, Mario Modesto-Mata, Marina Martínez de Pinillos, Bernardo Perea, Clément Zanolli & José María Bermúdez de Castro│Dental tissue proportions of European and African populations: sexual dimorphism

6.1. Mona Christensen, Robert J. Asher, Nicolas Di-Poï & Jukka Jernvall│Super-sizing teeth – from mice to elephants

6.2. Ona Saarnisalo, Mona Christensen, Pascal Schneider & Jukka Jernvall│Changing tooth shape and proportions using temporally restricted ectodysplasin treatments

1.1. Louise Souquet, Pauline Guenser & Nicolas Goudemand│Intraspecific variation and evolutionary trends in conodonts

1.2. Thomas Bertin, Béatrice Thivichon-Prince & Laurent Viriot│Review of evolution and relations between tooth implantation and tooth replacement in Amniota

1.3. Seela Salakka, Stephen Poropat, Ian Corfe & Benjamin Kear│Tooth growth and replacement rates of the sauropod *Euhelopus* revealed with synchrotron and conventional micro-tomography

1.4. Skinner│Enamel-dentine junction morphology of hominin mandibular third premolars

1.5. Laura Martín-Francés, María Martinón-Torres, Marina Martínez de Pinillos, Cecilia García-Campos, Mario Modesto-Mata & José María Bermúdez de Castro│2D molar tissue proportions in Early Pleistocene *Homo antecessor* (Atapuerca, Spain)

1.6. Gaël Becam & Tony Chevalier│The 3D enamel thickness of the permanent canines, premolars and first two molars in Neandertals and modern humans

8.1. Mario Modesto-Mata, Cecilia García-Campos, Laura Martín-Francés, Marina Martínez de Pinillos, Rebeca García-González, Yuliet Quintino, María Martinón-Torres, Christopher Dean & José María Bermúdez de Castro│Reconstructing worn cuspal enamel outlines in modern human permanent teeth. A new statistical approach and its application to dental growth studies

8.2. Itay Nudel, Nir Shpack & Rachel Sarig│Secondary dentin evaluation using Computarized Tomography: Application for paleodontology

8.3. Adeline Le Cabec, Michel Toussaint, David Begun, Paul Tafforeau & Christopher Dean│Imaging cementum in primate deciduous teeth using synchrotron phase contrast micro-tomography

8.4. Eric Pubert│Cementochronology: looking for improving thin section preparation for better results

8.5. Maire Malone, Laura Maclatchy, John Kingston & Guillaume Girard│Trace elemental distribution in the teeth of male *Papio cynocephalus* clarifies δ13C changes related to early dietary transitions

**14h45-15h45: Podium session 5. Odontology and paleodontology│Agora**

**Chair and discussant: Marin Vodanovic (University Hospital Centre Zagreb, Croatia)**

14h45-15h00: Heather Edgar, Corey Ragsdale & Kate Rusk│Dental Morphological evidence for Circum-Mediterranean population relationships and implications for Mestizos in North America

15h00-15h15: Bruno Maureille, Alan Mann, Maria-Dolores Garralda, Bernard Vandermeersch, Célimène Mussini, Sandrine Costamagno, Cédric Beauval, Véronique Laroulandie, William Rendu & Aurélien Royer│First description of partially digested Neandertal teeth, experimentation, results and other new discoveries

15h15-15h30: Yoli Bitterman, Itay Nudel, Ariel Pokhojaev & Rachel Sarig│Population characterization based on dentin trait: lower second premolar transverse crest

15h30-15h45: Laura González-Garrido, Susana Gómez-González, Luis Caro Dobon & Sofia Wasterlain│Periodontal disease in the Portuguese identified skeletal collections from the late nineteenth and early twentieth centuries: comparison between Central and Northern Portugal

**15h45-16h15: Coffee break│salle Badiane**

**16h15-17h15: Podium session 7. Genetics and epigenetics│Agora**

**Chair and discussant: Tuomo Heikkinen (University of Oulu, Finland)**

16h15-16h30: Christopher Stojanowski, Kathleen Paul, Andrew Seidel, William Duncan & Debbie Guatelli-Steinberg│Quantitative genetic analyses of dental crown morphology: exploring the genetic architecture of anterior tooth traits

16h30-16h45: Kathleen Paul, Christopher Stojanowski, Toby Hughes, Alan Brook & Grant Townsend│Exploring the genetic architecture of the human diphyodont dental complex: genetic correlation analyses of crown morphology

16h45-17h00: Kornelius Kupczik, Alexander Cagan, Silke Brauer & Martin Fischer│Learning from hairless dogs: The role of the FOXI3 transcription factor in mammalian dental development

17h00-17h15: Toby Hughes│Missing and extra teeth - the role of the epigenome

**17h15-18h00: Final discussion and announcement of awards winners│Agora**

The Excellence Initiative of Bordeaux supports the organization of ISDM IAPO 2017 by offering two prizes for young scientists (Master, PhD or Postdoc):

- The best podium presentation will receive the Albert A. Dahlberg award.

- The best poster will receive the Christy G. Turner award.

The winners will receive 750 € each from the Bordeaux Excellence Initiative (program funded by ANR - n°ANR-10-IDEX-03-02).

**Prizes committee: Horst Kierdorf (University of Hildesheim, Germany), Patrick Mahoney (University of Kent, UK), G. Richard Scott (University of Nevada, USA), B. Holly Smith (University of Michigan, USA), Huw Thomas (Tufts University, USA), Anne-marie Tillier (University of Bordeaux, France), Grant Townsend (University of Adelaide, Australia), Bernard Wood (George Washington University, USA).**

**20h00: Closing party│Hôtel Mercure Bordeaux Cité Mondiale  (tram B stop "CAPC Musée d'Art Contemporain")**

## SATURDAY, 7 OCTOBER

**7h00-20h00: Excursion to the Vallée de l'Homme in Dordogne**

The final day (October 7th) will be dedicated to an excursion to the Vallée de l'Homme in the Dordogne region.

- **7h00: bus departure from Bordeaux Place des Quinconces (tram B & C stop " Quinconces")**

The valley of Vézère contains more than 100 Palaeolithic sites and more than 20 decorated caves and has been listed as a World Heritage site since 1979.

The Musée National de Préhistoire des Eyzies offers a unique insight into this extraordinary rich prehistoric record.
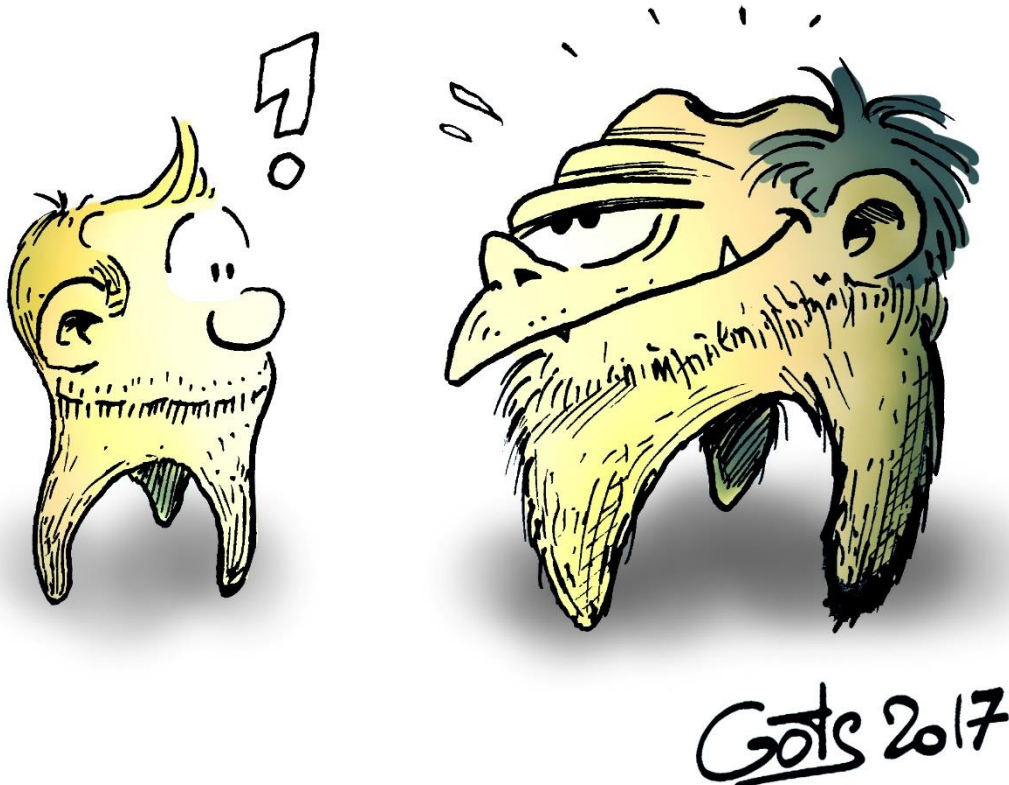
- **10h00-11h45: guided tour of Rouffignac**

One of the largest caves in the Périgord region, Rouffignac is a development of about eight kilometres of galleries on three levels with unusually large corridors. During the Magdalenian, prehistoric artists visited Rouffignac. The mammoth is a dominant theme, with 158 of these pachydermata representing in paintings on the walls and roof.

- **12h30-14h00: lunch at Regourdou**

- **14h00-16h00: guided tour of Regourdou (archaeological site, museum, bears parc)**

The site of Regourdou is located in the town of Montignac (Dordogne, France), on the left bank of the river Vézère. In September 1957, Neanderthal remains were found at this location, situated on the top of the hill which opens towards Lascaux cave. This accidental discovery was made by the landowner Roger Constant, and followed by a series of field seasons, directed by Eugène Bonifay, from 1961 to 1964. The site was initially interpreted as a unique Mousterian site with several anthropogenic deposits and an excellent preservation of a human skeleton and the remains of brown bears. From 2010 onwards, new archaeological investigations have been undertaken, allowing new interpretations to be made and stratigraphically confirming the status of the Regourdou 1 remains as one of the earliest Eurasian Neanderthal remains in such an excellent state of conservation (the finds include a near complete postcranial skeleton but the cranial vault is still missing).



*View on the west of the Regourdou site (Photo B. Maureille).*

Regourdou 1 as shown in 2007 for the 50th anniversary of its discovery (*Photo Ville de Périgueux. Collections et copyrights Musée d'Art et d'Archéologie du Périgord).*

- **16h00-17h00: free walk on the hill of Lascaux**

- **19h30-20h00: return to Bordeaux Place des Quinconces**

# ABSTRACTS

17th International Symposium on Dental Morphology & 2nd congress of International Association for Paleodontology

4-7 October 2017 – Bordeaux

# 1. Dental evolution in deep time

# The 3D enamel thickness of the permanent canines, premolars and first two molars in Neandertals and modern humans

Gaël Becam [*†1], Tony Chevalier [1]

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The teeth enamel thickness in hominins is of great interest for taxonomic purpose as well as to discuss growth processes or paleodiet. The 2D enamel thickness of Neandertals permanent teeth is relatively thinner compared to other hominins taxa, especially compared to modern humans. This derived feature in Neandertals was also observed in permanent molars by 3D methods. No study in the literature deals with the 3D enamel thickness for other permanent teeth, in particular the canines and premolars. In this context, we analyze the 3D enamel thickness of the upper and lower permanent canines and premolars in Neandertals and modern humans. Results are compared to those obtained from the first two molars. The total sample comprises 100 Neandertals, including an exclusive access to microtomographic data from the Hortus and Portel-Ouest sites (France), and 145 modern humans. Surprisingly no difference concerning enamel thickness was observed between these two samples for the first molars and the lower second molars. The results show that Neandertals have thinner enamel than modern humans for canines, upper premolars and second molars as well as for the fourth lower premolars. For these teeth, the absolute volume is very close between these two groups, but the surface at the enamel-dentine junction is significantly larger in Neandertals, and the absolute volume of dentine and pulp in crowns is greater compared to modern humans. However, the early Neandertals (MIS 5e) have larger crowns and thinner enamel compared to the late Neandertals (MIS 3), and the latter are close to the mean values of modern humans sample. This would suggest an endostructural reorganization of the crowns tissues in relation with a reduction of the crowns absolute volume. Nevertheless these results do not allow to be related to a significant geographical or diachronic variation in Neandertals.

**Keywords:** tooth, 3D AET, 3D RET

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# Serial homology, correlated evolution and phylogenetic signal in molars of placental mammals

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Serial homology is a type of intraorganismal homology, which generally consists in repetitive features sharing a large proportion of their genetic architecture and developmental pathways. Teeth constitute one of the main examples of serial homologous structures in vertebrates. As such, they exhibit high levels of integration, especially in homodont taxa. Placental mammals are initially characterized by a heterodont dentition parcelled into different modules (incisors, canines, premolars and molars). Because of their high morphological diversity and good preservation in the fossil record, teeth constitute a much used phylogenetic proxy in placentals. Cladistic analyses of morphological traits, which are essential to include fossil taxa in phylogenies, require independence between characters being scored in the analyzed matrices. Though covariation patterns within each dental module remain poorly known, repeated structures at successive dental loci are routinely scored as separated characters within cladistic analyses. Here we report the results of a large-scale investigation of the distribution of cingular crests on the upper molars of ca. 280 placental extant and fossil species. The analyses of phylogenetic co-distributions of the cingular crests on successive molars showed highly correlated evolution in the entire sample, demonstrating the serially homologous nature and the non-independence of these features at a macroevolutionary scale. Our survey also detected placental subclades in which the intensity of correlation between molars decreased and resulted in specific parcellation patterns related to molar sizes and underlying developmental mechanisms. Based on these results, we proposed different quantified models of evolution of the cingular crests on upper molars in placentals depending on the degree of integration in different parts of the tree, which may apply to many other repetitive dental structures. Finally, we make recommendations for the careful examination of the signal carried by serial homologues for phylogenetic analyses.

**Keywords:** cheek teeth, mammals, covariation, phylogeny, cingulum

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# Review of evolution and relations between tooth implantation and tooth replacement in Amniota

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Teeth are amongst the better preserved tissues in fossil, thus having a major importance in the study of evolution. Tooth replacement and tooth implantation are two major features characterizing the amniotes and their evolution. Nonetheless, the high diversity of both implantation and replacement types led previous authors to propose a variety of classifications to describe them, often not compatible or comparable with one another. The objective of this paper is, first to define a proper terminology to describe the diversity of tooth replacement and implantation in extant and fossil amniotes, then to take a look at the current knowledge concerning this diversity and its evolution, especially looking at the relationship between implantation and replacement. The redefinition of the terminology will go through splitting up in four major features: number of tooth generations, eruption movement, geometry of implantation, histological nature of the attachment. Thus, re-examined recent literature presents the ancestral state in Amniota as continuous dental replacement with a vertical eruption, thecodont with ankylosis. The evolution led to the loss of different bony walls surrounding the tooth sometimes associated with a reduction of the number of tooth generations. This overview of the currently known diversity of tooth implantation and replacement using a re-defined terminology is necessary to set a proper basis of the current knowledges on the dental evolution of Amniotes. This will allow a better understanding of the evolution of these features.

**Keywords:** tooth, implantation, replacement, Amniota, evolution

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# Enamel-dentine junction morphology of hominin mandibular third premolars

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Teeth are abundant in the fossil record and studies of their morphology continue to be central to hominin systematics. Tooth wear, however, often removes considerable information about the tooth's original shape and the presence and manifestation of discrete dental traits. The enamel-dentine junction (EDJ), which is preserved in teeth with moderate tooth wear, is increasingly being examined to maximize the taxonomic and phylogenetic data preserved in hominin teeth. Here we investigate the morphology of the EDJ in mandibular third premolars of fossil hominins. We use microtomography to image the EDJ in the largest sample of fossil hominins compiled to date (n> 60) and represented all major Plio-Pleistocene species (as well as extant non-human apes). We employ geometric morphometric analysis to capture the shape of the occlusal marginal ridge and the cervix, to compare relative cusp height, cusp spacing, crown height and cervix shape of the EDJ in shape and form space. Finally, we compared discrete traits such as the presence of accessory cusps and crests. Our results suggest that P3 EDJ morphology can be used to effectively discriminate between closely-related hominin species based on overall crown shape, and there are a number of discrete traits that differentiate particular species. For example, while apes and *Australopithecus anamensis* are unicuspid, a well-developed metaconid is variably present in *Au. afarensis*, and is consistently present in *Au. africanus, Paranthropus robustus* and *Homo naledi* (this condition is secondarily lost in later Homo). Also, the metaconid in *P. robustus* and *A. africanus* is rotated mesially relative to *H. naledi* and *Au. afarensis*. Modern humans and Neanderthals display a roughly circular cervix, which is not present in apes and earlier hominin species, many of which are expanded mesiobuccally. The implications of our results for hominin systematics and the taxonomic status of *Homo naledi* are discussed.

**Keywords:** premolar, EDJ, discrete traits, hominins, geometric morphometrics

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# Dental convergences and morphological diversity of the masticatory apparatus in extinct ungulate mammals

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During their evolutionary history, mammals underwent numerous events of diversification that resulted in a large variety of shapes and spectacular examples of morphological convergences. Notoungulates were a clade of endemic South American mammals, which appeared during the late Paleocene and became extinct during the Pleistocene. They encompassed generalist to more specialized forms, and presented a large diversity of cranial and dental sizes and shapes, including numerous convergences with extant groups of mammals. Interestingly, the intense periods of volcanism associated with increasing aridity occurring in South America from the late Paleogene onwards may have strongly impacted the evolution of these mammals. However, their phylogenetical relationships and their various ecological affinities still remain discussed, especially regarding the mosaic evolution of their masticatory apparatus. Here, we aimed at exploring more accurately the diversity of the masticatory apparatus in notoungulates mainly focusing on the last diverging and most specialized families. We performed a comprehensive study integrating analyses of dental growth and replacement, and quantification of skull shape with 3D geometric morphometric analyses in 70 specimens. We found that late diverging families present some striking dental morphological and ontogenetic similarities, such as high-crowned teeth, and fast dental eruption. These dental ontogenetic changes could have been associated on one hand with ontogenetic and structural adjustments within the jaw, and on the other hand with changing environments. Our morphometric analyses of the masticatory apparatus allowed documenting osteological changes accompanying these repeated dental innovations and evidencing the main morphological trends and convergences observed in late diverging families. Evolutionary trajectories of each clade are also discussed with respect to phylogenetical data, and in light of main functional and ecological assumptions.

**Keywords:** dental ontogeny, hypsodonty, dental eruption, geometric morphometrics, notoungulates

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# Ancestral state reconstructions of dental development in Miocene fossil taxa

Chrisandra Kufeldt [*† 1], Wendy Dirks [2], Bernard Wood [3]

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Primate fossil taxa from the Miocene are fundamental to understanding the evolutionary divergence between great apes and humans and remain an important taxonomic context with which to examine hominin evolution. Teeth remain the most abundant fossils, and reconstructing dental development using dental microstructure provides information on the life history of fossil taxa. While numerous studies have described dental development in Miocene fossils in relation to modern apes, none have evaluated whether the ontogenetic record preserved in dental microstructure provides insight into the evolutionary relationships of fossil and extant primate taxa. This study reconstructs the ancestral state of enamel growth in the living apes to determine whether any of the Miocene fossil taxa with reported enamel development are a potential candidate of the last common ancestor of the great apes. Dental microstructure traits reconstructed included daily secretion rate, periodicity of long-period Retzius lines, extension rates, cusp-specific molar crown formation times, cuspal enamel thickness, and perikymata counts measured from a sample of 42 extant primates combined with 14 Miocene fossil taxa. Results suggest that the fossil taxa *Anapithecus hernyaki* and *Vicotoriapithecus macinnesi* express character states consistent with the expected basal nodes for the Cercopithecoidea, with *Victoriapithecus* sharing more ancestral states with the expected ancestral state of the papionini primates. The reconstructed ancestral states of the great apes suggest that none of the Miocene fossil apes with known dental development data make good ancestral candidates, and that the last common ancestor exhibited rapid enamel development relative to the living apes.

**Keywords:** ancestral state, reconstruct, Miocene, fossils, cuspal daily secretion rate

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# On the evolution (and devolution) of whale and dolphin enamel

Carolina Loch *† 1, Jules Kieser 1, R. Ewan Fordyce 2

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2 Department of Geology, University of Otago, Dunedin, New Zealand

Cetaceans (dolphins and whales) are unusual mammals with disparate skulls and feeding apparatus well-adapted for life in the water. Extinct archaeocetes, the ancestors of modern whales and dolphins, had elongated jaws and differentiated teeth, similar to terrestrial mammals in shape and number. Conversely, most living dolphins have multiple simplified conical teeth, while living baleen whales have no adult teeth. This study investigated the evolutionary changes in the enamel ultrastructure of fossil and modern whales. Teeth of extinct archaeocetes, and fossil and living toothed whales were analysed. Fossils from the Southern Hemisphere date from ~25 to 4 million years. The living species studied represent a mix of tooth/body sizes and feeding strategies. Dental samples were embedded, cross and longitudinally sectioned, polished, etched, coated with palladium and analysed via scanning electron microscopy (SEM). In archaeocetes and some fossil toothed whales with differentiated dentitions, inner enamel was organized in Hunter-Schreger bands (HSB) with an outer layer of radial enamel. Other fossil toothed whales with multiple simplified teeth showed a simpler structure with inner radial and outer prismless enamel. Most living dolphins had radial enamel with an outer layer of prismless enamel, with exception of the Amazon River dolphin which retained HSB. Porpoises showed even simpler enamel structure with prismless enamel throughout the crown. The evolutionary adaptation of dolphins and whales for feeding in water resulted in reduced occlusion and mastication, and evolution of suction-feeding. This lead to reduced biomechanical functional demands with concomitant simplification of the tooth morphology and enamel ultrastructure, and simplification of jaw muscles. The evolution of the enamel layer in cetaceans shows a unique trend toward reduction in complexity over time.

**Keywords:** Aquatic feeding, Cetaceans, Hunter, Schreger bands, Prismless enamel, Radial enamel

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# Application of micro tomography to the mandibular incisors of Sima de los Huesos

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Dental tissue proportions are regularly reported as a diagnostic feature within hominin characterization, and are linked to dietary reconstructions and non-masticatory function. Until recently dental tissue proportions were inferred from linear measurements extracted from physifically slicing teeth, or observing natural random fractures in teeth; these irregular and destructive methods have been critiqued heavily. Microtomography has led to advancements in this field, with standardised non-destructive methods applied to valuable fossils, allowing for larger samples to be analysed with high resolution. Hominoid incisors are severely under investigated in the archaeological record for all aspects of dental tissue measurements, despite implications to non-dietary behaviour. Studies into Neanderthal anterior dentition have reported that they are larger than expected, and adapted to heavy wear and frequent loading. Important excavations at SH represent a Middle Pleistocene population belonging to a much wider group of sites found at Sierra de Atapuerca (Burgos, Spain), widely renowned for significant contributions to the study of human evolution. A large accumulation of hominin remains have been systematically excavated from SH, with 62 of the 525 permanent teeth identified as mandibular incisors. Analysis of SH material has had significant implications concerning the origin of *Homo neanderthalensis*, and provides an excellent opportunity to study a hominin population constrained geologically and temporally. Here we report the results, using MicroCT and geometric morphometric analysis, of Sima de los Huesos (SH) mandibular central (6) and lateral incisors (8). A comparative sample of modern humans (35) and Neanderthals (7) will also be examined, this will aid in phylogenetic analysis of the SH material expanding valuable data sets, and hopefully encourage further research into anterior dentition. Results indicate that the SH population holds an intermediate position between Neanderthals and modern humans, with a notable increase in dentine surface area relative to modern humans.

**Keywords:** Atapuerca, dental tissue, microtomography, incisor

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# Feeding habits of terrestrial monkeys track paleoenvironmental conditions in Omo Valley, Plio-Pleistocene of Ethiopia

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The Shungura Formation, a geological formation situated within the Lower Omo Valley in Ethiopia, has delivered major Plio-Pleistocene paleontological and archeological contents, including numerous hominin and lithic remains. The spatial extension and chronological continuity of its sedimentary outcrops, notably between 3 Ma and 2 Ma, has allowed to shed light on this critical period in hominin evolutionary history, marked by the transition between *Australopithecus* and *Homo*, and by the emergence of robust australopithecines. In this study, we assess the environmental variations through time in exploring the feeding habits of two most abundant primates recovered in this geological formation: *Theropithecus* and *Papio*. Besides, their present-day relatives are terrestrial and forage intensively on the herbaceous layer and on underground organs. A Dental Microwear Textural Analysis is performed on phase I (shearing) and phase II (crushing) molar facets of 75 specimens of *Papio* and 154 of *Theropithecus* from geological members B to G, covering a time window ranging from 3.44 Ma to 2.05 Ma. The analysis show generic differences when crushing facets are considered, and generic and member differences when the analysis is focused on the shearing molar facets. *Papio* has higher complexity and heterogeneity of complexity than *Theropithecus*, supporting that the baboons ingested harder/less tough food items than the gelada relatives. When looking at variations through time, we may conclude that *Theropithecus* recovered in members C and F have ingested a higher proportion of tough plants than their relatives from other geological units. Noticeably, after the first occurrence of *Homo*, there is a significant shift with tougher foods in the diet (between members E and F) for *Theropithecus*; a same trend, although not significant, is noticed for *Papio*. This suggests a rapid expansion of open habitats between 2.40 Ma and 2.33 Ma.

**Keywords:** Africa, Cercopithecidae, Diet, Environment, Microwear

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# 2D molar tissue proportions in Early Pleistocene *Homo antecessor* (Atapuerca, Spain)

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Teeth possess a strong genetic expression, which can be useful for taxonomic and phylogenetic inferences in hominins. Despite being widely investigated, the taxonomic signal of enamel thickness in the genus *Homo* remains unclear due to the scarcity and preservation of the fossil remains. Genus *Homo* is known to possess thicker relative enamel compared to living African Great apes. Within the genus *Homo*, different trends in enamel thickness were observed between older and younger taxa as well as among geographic groups. In particular, molar tissue proportions have been useful to distinguish between Neanderthals and modern humans. However, little is known about the polarity of this feature. The dentition and skeletal morphology of *Homo antecessor* presents an admixture of primitive and derived traits shared with Neanderthals and *H. sapiens*. In this study we calculate the 2D molar tissue proportions in *H. antecessor* to: i) characterize the molar enamel thickness in this population; ii) provide new insights about the polarity of the enamel thickness within the genus *Homo*; iii) assess how different is *H. antecessor* population in relation to Neanderthals and modern humans. We applied mCT imaging to Early Pleistocene *H. antecessor* molar collection (n=17), calculated the relative enamel thickness and average enamel thickness, and compared the results with fossil hominins and modern humans. Our results indicate that the relative enamel thickness of *H. antecessor* molars is generally higher than in Neanderthals and closer to *H. sapiens* values, except for the upper first molar. The polarity of the enamel thickness in the genus *Homo* is discussed to the light of these results. Future studies in other Early Pleistocene hominins may shed further light on the evolutionary meaning of this feature.

**Keywords:** Early Pleistocene, Hominins, Homo antecessor, mCT technique, enamel thickness

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# Tooth growth and replacement rates of the sauropod *Euhelopus* revealed with synchrotron and conventional micro-tomography

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Sauropod tooth morphologies and tooth replacement patterns can provide important information on sauropod feeding habits and evolution. *Euhelopus* is an Early Cretaceous somphospondyl neosauropod, and belongs to the group Euhelopodidae, usually placed as a close relative of Titanosauria. *Euhelopus* is a key taxon in the evolution of sauropod teeth as it displays a conservative tooth morphology compared to Titanosauria, despite the close relationship. The spoon-shaped teeth of *Euhelopus* resemble those of *Camarasaurus*, a more basal macronarian, as well as many non-neosauropodan taxa not closely related to *Euhelopus*.

We used high-resolution synchrotron X-ray micro-tomography to identify growth rate recording von Ebner growth increments in the dentine of *Euhelopus* teeth. In *Euhelopus*, these are spaced on average 14.5 m apart, similar to reported spacings for *Diplodocus* and *Camarasaurus* (both 15 m) but lower than those of unidentified titanosaurs (19-21 m) from Late Cretaceous Argentina. We also used conventional CT to identify replacement teeth in upper and lower jaws of *Euhelopus*. There are two/three replacement teeth per functional tooth, depending on jaw position. Using replacement rate estimates based on tooth length, we find an average rate of 38 days (upper teeth) and 55 (lowers). These values are slower than the diplodocoids *Dicraeosaurus* and *Nigersaurus*, slightly slower than *Diplodocus*, but faster than *Camarasaurus*. This suggests that moderately fast tooth replacement had evolved for the robust, conservative tooth morphology of *Euhelopus* at a node on the lineage leading to Titanosauria, before the independent evolution of pencil-shaped teeth in both Euhelopidae (Phuwiangosaurus) and elsewhere in Somphospondyli. Although we show here that the evolution of tooth shape and tooth replacement rate was uncoupled in at least Euhelopodid sauropods, the repeated evolution of pencil shaped teeth and fast replacement rates indicates that there was a strong evolutionary pressure in these directions for sauropods in varied places and times.

**Keywords:** Sauropod, replacement, growth, increment, synchrotron

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# Patterns of metameric variation in premolar root morphology in fossil hominins

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Premolar root morphology, both external and internal, which varies within and between species in extant non-human apes, modern humans, and fossil hominins, has been used to inform taxonomic and phylogenetic hypotheses within the hominin clade. Previous studies have identified two predominant trends during hominin evolution: a reduction in root number from *Australopithecus* to *Homo*, culminating it a predominance of single rooted maxillary and mandibular roots in modern humans; and an elaboration of root complexity in megadont *Australopithecus* taxa. In this study we report on patterns of intra-individual metameric variation, which has traditionally received less attention, but has potential as a character for use in hominin systematics and to broaden our understanding of the developmental processes underlying root variation. We use microtomography to characterize metameric patterns in hominin mandibular and maxillary premolar external morphology and canal form in a taxonomically broad study sample (n 126 pairs) including all major Plio-Pleistocene hominin species (*Australopithecus anamensis, A. afarensis, A. africanus, Kenyanthropus platyops, A. boisei, A. robustus, Homo habilis, H. rudolfensis, H. ergaster, H. erectus, H. heidelbergensis, H. neanderthalensis,* and fossil *Homo sapiens*). Premolar morphology was assessed from 2D cross-sectional images at mid-root with a 3D assessment being taken when root form was not clear from the 2D section. We find more metameric intraspecific variation than previously recognized (16 combinations in maxillary premolars and 22 combinations in mandibular premolars). Some species, such as *A. robustus*, are characterized by up to six combinations of maxillary premolar pairs and nine combinations of mandibular premolar pairs. We discuss how these results inform our current understanding of evolutionary developmental transitions in metamerism during hominin evolution, as well as their impact on using root morphology to help reconstruct hominin phylogeny.

**Keywords:** hominin, premolars, roots, canals, metamerism

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# Intraspecific variation and evolutionary trends in conodonts

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How shape changes through time? This question is central to paleontology as most of the record is morphological in nature. There is a long tradition of research on how forms are ruled, and therefore on how developmental processes determine the morphological variation of individuals in ontogeny and through evolution. The set of theoretically possible forms is thus bounded by the way these forms can be generated during ontogeny, possibly driving evolution into preferential directions. To date, patterns of shape variation in conodont elements have been documented mostly qualitatively and at the species level (e.g. within taxonomic diagnoses) and no generalized pattern of variation has been described. Because conodont elements are used for feeding, their complex morphology, in particular recurrent homeoplasies, may reflect, functional adaptations to specific diets. Yet, they must also reflect developmental constraints. In order to constrain our interpretations of presumed adaptation to diets and environments, it is thus mandatory to better understand if and which traits might be adaptive or not. Conodont elements are likely highly integrated, that is their morphological characters are not independent but covary with each other. In this study, we investigate patterns of intraspecific variation in two very distinct and distant evolutionary lineages, one from the Late Devonian, and one from the Late Triassic. In both cases, empirical observations have led some authors to hypothesize evolutionary trends in conodonts morphology. Here we are assessing those `trends' in a quantitative way. For this purpose, populations of P1 elements of each species have been digitized using a CT-scanner. We performed geometric morphometrics analysis to compare the shape of the P1 elements quantitatively. We seek to identify generic rules of conodont morphology, for instance patterns of covariation that would be shared by these two lineages and whose validity could then be extended to other taxa.

**Keywords:** conodonts, evolution, developmental constraints, patterns of covariation, intraspecific variation

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# Adaptive dental evolution in African suids: insights from new Plio-Pleistocene samples of *Kolpochoerus* from the Shungura Formation (Lower Omo Valley, Ethiopia)

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Identifying the selective forces responsible for dental adaptations at the geological time scale is a major research topic in evolutionary sciences. Dramatic adaptations in dental morphology are documented in detail in the fossil record of African suids. Convergent iterative evolution of extremely specialized dentitions (most notably increased length and height of third molars) occurred in several clades, presumably as adaptations to diets dominated by abrasive tropical grasses. Here we provide new data on the morphological changes within one lineage of *Kolpochoerus* through the Plio-Pleistocene sequence of the Shungura Formation (Lower Omo Valley, southwestern Ethiopia), notably using new fossils collected since 2006 by the Omo Group Research Expedition. We also combine dental microwear textural analyses and enamel stable carbon isotopic data to reconstruct the ecological changes. From ca. 3.0 Ma to ca. 1.0 Ma, length of the third molars increased progressively whereas height of third molars increased progressively from ca. 3.0 Ma to ca. 1.6 Ma but then abruptly at ca. 1.6 Ma, marking the transition to a more derived species. Stable carbon isotopes of enamel indicate a strong and abrupt increase in the consumption of C4 plants at ca. 2.8 Ma. New analyses of dental microwear texture indicate little change from ca. 2.8 Ma to ca. 1.0 Ma with overall low complexities and low heterogeneities of the surfaces of the shearing enamel facets, which resembles most the data for *Phacochoerus*, the only extant suid specialized on grasses. Combined with the stable carbon isotopes, those new data allow us to infer that *Kolpochoerus* consumed large amounts of C4 grasses as early as ca. 2.8 Ma in the Lower Omo Valley, with a very limited associated morphological response, and through the sequence up to ca. 1.0 Ma. We propose a new ecological scenario to explain this discordance.

**Keywords:** Suidae, dental adaptation, grass, dental microwear texture, stable carbon isotopes

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# 2. Teeth and archaeology (humans & animals)

# Sheep birth distribution in past herds from oxygen isotope analysis in teeth: a review for prehistoric Europe (6th - 3rd millennia BC) and the comparative use of upper and lower molars for this purpose

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In temperate latitudes sheep have a seasonal reproductive behaviour, which imposes strong constraints on husbandry in terms of work organization and availability of animal products. Researches in animal agriculture over the last 50 years have focused on understanding the physiological and environmental mechanisms driving this cycle, and trying to find ways to control it. This characteristic is inherited from their wild ancestor. However the history of its evolution over the ten millennia that separates present day European sheep from their Near Eastern ancestors' remains to be written. Information related to birth seasonality may be retrieved directly from archaeological sheep teeth. The methodology consists of reconstructing the seasonal cycle record in sheep molars, through sequential analysis of the stable oxygen isotope composition ($\delta 18O$) of enamel. Because the timing of tooth development is fixed within a species, inter-individual variability in this parameter reflects birth seasonality. A review of the data obtained from European archaeological sites dated from the 6th to the 3rd millennia BC will be provided. We will also define to what extent upper and lower molars may be equally used for this analysis, with reference to their timing of formation. This methodological point is addressed on paired upper/lower M2s and M3s from modern sheep.

**Keywords:** tooth enamel, oxygen isotopes, birth seasonality, sheep, upper/lower dentition

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# Detecting taxonomic and phylogenetic signals in equid cheek teeth: towards new palaeontological and archaeological proxies

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The Plio-Pleistocene evolution of *Equus* and the subsequent domestication of horses and donkeys suffer from the lack of phenotypic markers capable of tracing this evolutionary process in the paleontological/archaeological record. Using images from 345 specimens, encompassing 15 extant taxa of equids, we quantified the occlusal enamel folding pattern in four mandibular cheek teeth with a single geometric morphometric protocol. We initially investigated the protocol accuracy by assigning each tooth to its correct anatomical position and taxonomic group. We then contrasted the phylogenetic signal present in each tooth shape with an exome-wide phylogeny from 10 extant equine species. We estimated the strength of the phylogenetic signal using a Brownian motion model of evolution with multivariate *K* statistic, and mapped the dental shape along the molecular phylogeny using an approach based on squared change parsimony. We found clear evidence for the relevance of dental phenotypes to accurately discriminate all modern members of the genus *Equus* and capture their phylogenetic relationships. These results support the use of dental morphology as a key marker for both paleontologists and zooarchaeologists to explore the evolutionary history of the horse family, up to the latest domestication trajectories of horses and donkeys.

**Keywords:** Equus, Manidular teeth, Geometric morphometrics, phylogenetic signal, fossil

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# All shapes and sizes: variation of tooth form between and within historic populations from Southern Britain

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Tooth form represents a physiological response to environmental constraints, biology and cultural systems, on both an individual and populational level. Studies of these factors largely focus on the crown and infrequent tooth root studies are predominantly qualitative. This paper will quantitatively investigate the potential use of tooth form to investigate these factors. Intrapopulation and microevolutionary tooth form variation will be studied between and within historic populations, using Anglo-Saxon and Medieval samples from Southern Britain. Archaeology can be transformed by digital high-quality non-destructive techniques, such micro-CT, as equipment becomes increasingly accessible. Micro-CT allows the investigation of hidden structures and enables the acquisition of both size and shape phenotypes in fine detail. This can be combined with geometric morphometric analysis to facilitate the obtainment of new shape phenotypes. Specimens were μCT scanned (Skyscan 1272, Anthropology imaging laboratory, University of Bristol) at a 17.5 μm resolution. Enamel, dentine and whole-tooth surfaces were extracted by grayscale threshold segmentation, with virtual calculus removal, and aligned in space. Using these surfaces, tooth tissue proportions were obtained. Tooth shape was studied using Geometric Morphometric analysis. This method was employed to overcome the problem of subjectivity and information loss encountered when relying on non-metric traits and metric measurements. Environmental, biological and cultural factors were considered and it is likely that it is a combination of these factors that results in tooth form. However, tooth root form appears to be indicative of tooth function, and may be a potential future tool to infer functional variation.

**Keywords:** Dental Morphology, Tissue Proportions, Variation, Geometric Morphometrics, Micro-CT

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# Comparing the rates of dental wear of two archaeological populations and their implications to Brothwell's method

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Ever since the work of Broca, dental wear has been used to estimate age, an approach that is still widely used by bioarchaeologists. Teeth are subject to constant wear throughout an individual's life resulting in the loss of dental tissue which produces a predictable pattern of exposed dentine. It is this pattern that has been used to estimate age in skeletal individuals. The most widely cited method using this approach was produced by Brothwell, who stated that it could be used to estimate age in remains dating from the Neolithic to the Medieval period. This statement, however, has not been evaluated. This paper investigates this statement using well-documented collections dating to the Iron Age and Anglo-Saxon periods. Using statistical analysis the rate of wear for each period is calculated and compared. The rate of wear is calculated using two measurements of dental wear. The first uses the traditional technique of an ordinal scale and a second using the quantitative measurement of crown height. Comparing the wear rates produced from these measurements for the two periods will provide insight into the accuracy of Brothwell's statement and help to answer the question: can a single age estimation chart using dental wear be applied to multiple archaeological periods?

**Keywords:** dental wear, age estimation, Brothwell, bioarchaeology

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# An evaluation of the oral health of a late antiquity human sample from Piazza Corrubbio-Verona, Italy

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The necropolis of Piazza Corrubbio, dating back to Late Roman age, has been brought to light in Verona-Italy in 2009, and an emergency excavation (conducted in cooperation with the Soprintendenza del Veneto between 2009 and 2010) allowed the discovery of 249 tombs belonging to various typologies (the "cappuccina" graves, those in pottery amphorae-mostly used for children burials- the brick and stone coffins and simple graves dug into the ground) together with few archaeological structures. The human skeletal remains and the archaeological materials are currently being studied by the Ca Foscari University of Venice and Archeolab Ca' Foscari, in a joint cooperation project with the Superintendency, directed by Prof. Francesca Bertoldi and Prof. Daniela Cottica. Among the dental diseases and stress indicators considered in this study such as caries, calculus, teeth loss, abscesses, hypoplasia and teeth wear, we paid particular attention to the presence of periodontal disease, to evaluate its impact on the oral health of ancient populations and above all, to test a method of scoring and recording this pathology in order to focus on a single population study but also to contribute to the understanding of epidemiology, history and importance of this disease, that needs to be fully appraised and correctly evaluated in the frame of the general health status of a population. Our methodology relies on the recording of periodontal disease commonly applied to living subjects to make an easy, simple diagnosis, through the measurements and evaluation of horizontal and vertical bone loss in alveolar cavities. For a better comprehension of the age of the periodontal disease's onset, we applied, together with "classical" anthropological techniques of age diagnosis, the radiographic age determination method for adults proposed by Prof. R. Cameriere's, measuring the reduction in size of the pulpar chamber of canines, as age increases and secondary dentin develops.

**Keywords:** forensic odontology, Cameriere's method, periodontal disease, dental paleopathology, physical anthropology

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# Non-masticatory dental wear of anterior teeth in Late Neolithic individuals from Alicante (Spain) burial caves and rock shelters

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Non-masticatory dental lesions (chipping, notching, interproximal grooving and lingual surface attrition of the maxillary anterior teeth) are especially helpful to assess the impact that dietary and social-cultural habits had on ancient populations. The aim of the present study was to record and describe the unusual dental wear pattern observed macroscopically on 252 anterior teeth from the Late Neolithic and located in 14 burial caves and rock shelters in Alicante, southeast Spain. All the teeth studied were isolated thus sex and age differentiation was not possible. Therefore, only permanent complete erupted teeth were examined. Results suggests the teeth were used in a habitual practice as a 'third hand', based on the morphology, distribution and grade of the dental wear. All the burials samples exhibit an 'incisor-dominant' pattern, showing a greater representation of dental chipping in comparison to the other non-masticatory dental wear. No interproximal grooving was found on anterior teeth. The study of non-masticatory dental lesions encourages to provide a new insight on how populations used their dentitions in ancient times.

**Keywords:** non-masticatory dental wear, Late Neolithic, burial cave, rock shelter, Spain

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# Seasonality studies using dental cementum analysis of ungulate hypsodont teeth: issues and perspectives

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Among the different types of dental cementum present in mammal teeth, the acellular extrinsic fibre cementum (AEFC) is the most useful for ageing and seasonality studies in archaeology because of its regular and continuous growth on the cervical parts of the root. However, if this type of cementum is commonly observed in brachyodont teeth, this is not always the case in the high-crowned cheek teeth of several families of ungulates (bovidae, camelidae, etc.). In response to the continued vertical displacement and intense occlusal wear of these hypsodont teeth during a major part of their life, complex mechanical stresses can affect the cementum growth and result in a production of cementocytes in place of or along the AEFC. Such pattern, generally corresponding to a cellular mixed stratified cementum (CMSC), impedes the observation of the alternating seasonal bands of cementum. Therefore the seasonal information given by the nature and depth of the last increment can be very difficult to extract from the teeth of animal groups which are sometimes common in the archaeological sites, like ibex or horse in European Paleolithic, or like most of the domestic ungulates in more recent times (cattle, sheep, goat). In order to better understand the dynamic growth of the cementum in hypsodont teeth, we performed the analysis of thin-sections of teeth from animals of known season at death belonging to seven distinct species (bison, cattle, mouflon, sheep, goat, chamois and horse). Based on the first results of this study, we describe here a number of criteria and conditions of microscopic observation, combined with optical filters (cross polarization, wave plate), allowing to select adequately the most optimal regions of interest within the cementum layer and to increase the reliability of the identification of the last increment for seasonality studies.

**Keywords:** archaeology, dental cementum, seasonality, zooarchaeology, methodology

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# Dental morphological changes in the Levant populations during the Holocene

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The transition into a food producing society had substantial influences on human physiology. The Agriculture revolution with its biological and cultural changes was suggested to be the cause for physiological and morphological changes in the masticatory system in general and at the dentition in particular. In the current study, we aim to evaluate dental morphological modifications in the upper first molars in the Levantine populations during the Holocene, especially following the agriculture revolution. Four populations were included in this study; Natufian hunter-gatherers ( ~14,900-11,750 BP), Neolithic farmers ( ~12,175 - 8250 BC), Chalcolithic ( ~4,500-3,300BC), and recent subjects. Eighty upper first molars were scanned using a µCT50 system (Scanco Medical AG, Switzerland); segmentation and 3D reconstruction were performed using Amira 6.1 software. Rhinoceros SCS v5 software was used to carry out morphology measurements. The geometric morphometric analysis included enamel-dentine junction (EDJ) shape and cervical and crown outline analyses. Statistical analysis included principal components analysis (PCA) which plotted the morphometric parameters. The cervical outline and crown outline size had shown a gradual decrease among the studied populations, from the Natufian to Modern human population respectively. We noticed morphological trends and differences indicating gradual morphological changes during the Holocene. The geometric morphometric analysis indicates a gradual change in size and morphology of the upper first molar in the Levantine populations. These changes coincide with the cultural and nutritional changes and the physiological changes at the jaws following the agriculture revolution.

**Keywords:** Crown outline, geometric morphometric, agriculture revolution, EDJ analysis, permanent maxillary first molar

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# Diet of the early Medieval elites (Great Moravian Empire, 9th - 10th century AD, Czech Republic): synthesis of geochemical methods and virtual anthropology

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The main aim was to study the influence of social status on diet in the early Medieval population from the Mikulcice settlement (Czech Republic) using a combination of invasive and non-invasive dental anthropological methods. Mikulcice was the foremost centre of Great Moravia. Previous studies of the sample show socio-economic differences in various osteological markers which can be explained by distinct dietary behaviour of the social classes. Nevertheless, the elite graves have never been studied; and therefore, the real nature of the dietary differences remains unclear. Our sample consisted of upper second molars of forty individuals from elite graves (as defined by grave goods) and a comparative sample of non-elite individuals (III church). Each M2 was extracted and scanned using Skyscan 1172 and the high resolution micro-CT scans were semi-automatically segmented in image segmentation software Avizo 6.0. The topographic maps of enamel thickness were created from 3D surface models and 2D enamel thickness was measured from the virtual cross-sections through mesial cusps. Stable isotope analysis was performed on two samples from each individual. First, compact bone of rib was sampled to reconstruct adult dietary behaviour. Second, the upper part of the M2 root was sampled to reconstruct the diet at the age of 8 to 10 years. The preliminary results of isotopic analysis suggest socio-economically motivated differences in the consumption of animal protein. These differences were already present during childhood and continued into adult age. These results are confronted with the enamel thickness data of the concerned individuals. This unique combination of geochemical methods and virtual anthropology at the individual level has not been used before.

**Keywords:** diet, enamel thickness, stable isotope analysis, virtual anthropology, early Medieval period

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# Gangs with fangs: contribution of cementum analysis towards the understanding of human and hyaena seasonal settlements in Belgium during the Late Pleistocene

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Deciphering the seasonality of predation is a key question in prehistoric archaeology to comprehend spatiotemporal strategies adopted by human groups to overcome fluctuating ecological and environmental pressures throughout the year. In North-West Europe, despite recurrent rough environmental conditions (e.g. cold temperatures, heterogeneity of raw material access), the Belgian mosan basin was regularly occupied by human groups during the Late Pleistocene, probably taking advantage of the ungulate biomass and the numerous natural shelters o ered by the karstic valleys. They however had to share this attractive region with plenty of other large predators, cave hyaenas in particular, which were in direct and indirect competition with them. Here, we explore the seasonal patterns of human occupations and compare this to pattern of hyaenas in order to highlight the possible annual adaptive ecological niche differentiation. To this end, we undertook a unique multitaxa, multisite cementochronological study in the region and have tested for the very first time the seasonal settlements of hyaenas. We have analyzed about 20 teeth from 3 different sites with anthropogenic as well as hyaena-accumulated assemblages. Thanks to our new standardized protocol for cementum analysis (CemeNTAA project) and a detailed faunal study, we obtained new seasonal data on both predators. Interestingly, it appears that humans occupied the mosan basin mostly during cold seasons, whereas seasonal signals of hyaenas seem more heterogeneous. This study shows that the analysis of the incremental structures of palaeofaunas permits to gauge the extent of the interspecific competition between humans and their main competitors and to test the validity of a "refuge-zone" hypothesis for human groups in the Meuse valley.

**Keywords:** cementochronology, seasonality, settlement patterns, Late Pleistocene, Northwest Europe

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# Show me your teeth: dental anthropology as evidence for biological affinities and cultural practices in Urkesh (Syria) during the Middle Bronze Age

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The results obtained recently through the archeo-anthropological analysis of Urkesh funerary space allowed us to shed light on a panel of various funeral gestures. If some correspond to the characteristic funerary norms of Mesopotamia for the Middle Bronze age, others (e.g., deposits of fire structures or animal remains around some tombs) are entirely atypical. Hence, we concluded that these practices reflect the will of Urkesh's inhabitants to bury some individuals differently from others. In some cases, the reason behind such distinction was shown to be related to biological identity of the deceased (e.g., jar burials are reserved for children less than 6 years old), while, for others, kinship and/or social status were envisaged. Our current study takes a special interest in these two latter parameters through the prism of dental analyses. The kinship is apprehended by the study of biological affinities between sampled individuals from the Urkesh's elite, whereas the social status is investigated by reconstructing diet patterns and oral health status of these individuals. In total, our corpus is made of 75 teeth belong to high-ranking children and adults buried in single and plural graves. Graves were selected to cover the entire funerary space. We performed different non-destructive approaches of such rare material, i.e. by analysing 1) metric and non-metric dental traits, 2) macro- and microwear of tooth occlusal surfaces through macroscopic observation as well as scanning electron microscopy (SEM) and micro-computed tomography (CT scans), and 3) dental paleopathology (caries and enamel hypoplasia). The obtained results will provide us information about 1) spatial organisation of Urkesh funerary space according kinship and social status of the buried individuals, 2) physical properties of the foodstuff consumed and some of the cultural habits, and more broadly 3) the biological ties (sensu lato) connecting ancient Near Eastern populations with each other.

**Keywords:** Biological distance, dental morphology, macro, and microwear, diet, Mesopotamia

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# Geometric morphometrics of molar teeth of South American Camelids: an exploratory approach for taxonomic identification of modern and archaeological individuals

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South American camelids (SAC) have been a key component of Pre-hispanic cultures. According to morphological and genetics criteria, SACs are classiffied into two genus, *Lama* and *Vicugna* and four modern species: two wild, the vicuna (*Vicugna vicugna* Molina, 1782), and the guanaco (*Lama guanicoe* Müller, 1776) and two domestic, the llama (*Lama glama* Linnaeus, 1758) and alpaca (*Vicugna pacos* Linnaeus, 1758). Llama and alpaca are the unique large domesticated mammals on the American continent. However, their taxonomic identification in the archaeological records remains challenging for zooarchaeologists due to their morphological similarity. To get a greater insight into the interaction between SACs and Pre-hispanic societies, a clear distinction between the four species is highly required. Here we investigate the potential of cheek teeth morphology captured by geometric morphometrics to access a reliable taxonomic signal at the species level. We used the occlusal enamel folding pattern of lower and upper molars as phenotypic marker. We used 58 modern specimens of the four species from museum collections to investigate whether the taxa could be distinguished and whether the effects of age and size through wear had a deleterious effect. Secondly, we compared these modern taxa with archaeological specimens from Peruvian sites belonging to the Mochica (100 to 800 AD), Transitional (800 to 1000 AD), Lambayeque (850 to 1300 AD) and Chimu (1000-1450 AD) cultures to predict their taxonomic affiliation. Results show that there is an important age effect which impacts the enamel form pattern, consequently we can't distinguish the 4 modern taxa. Besides, the variation of archaeological specimens strongly differs from modern taxa, suggesting that Pre-hispanic diversity is too different from the modern SACs' one to be used as a reliable comparative materia. Therefore, to identify the past SAC's diversity we must rely on ancients' samples and also investigate other cranial or post-cranial markers.

**Keywords:** South American Camelids, taxonomy, geometric morphometrics, molars, zooarchaeology

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# New insights into the Mousterian Human teeth from Lezetxiki cave (Arrasate, Basque Country)

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The teeth from Lezetxiki (Arrasate, Basque Country) were found in 1966 and studied in 1970 by Basabe. From this time on, revisions on the teeth have been made, but these have been conservative and no novel data has been published. Meanwhile plenty has been analyzed about the context where they were found, as the digging of the site has recently been nished. This has revealed the ambiguous nature of the assemblage and raised some questions about the nature of the relationship between the teeth and the associated materials. For example, the radiocarbon dating obtained for the context situates the strata in > 47,000 BP2, which indicates that the lithic materials showed advanced features in a late Mousterian context. In the present work, we present results of the external and internal morphology of the two teeth (Upper Molar and Lower Premolar) obtained with up to date methods (such as µCT scanning), and the comparison of the characteristics of these teeth with data that was not available at the time of the first study. Results confirm that these teeth show Neanderthal features. The lower premolar that was previously described as a P4 is actually a P3.

**Keywords:** Neanderthal, microCT scanning, morphometrics, tooth morphology

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# Dental fluctuating asymmetry in Portugal: developmental instability in Valenca and the Coimbra reference sample

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Fluctuating asymmetry (FA) is commonly used to estimate developmental instability (DI), the organism's response to ontogenic disturbance. This work aims to (1) select nonmetric dental traits for FA testing, according to representativeness and comparability; (2) test DI differences between Valença and Coimbra, two Portuguese samples. Valença (VLN) is a 17th-19th century rural sample of 31 individuals from a Fortress in the northern border of Portugal. Coimbra (COI) is a 19th/20th century sample of 600 individuals from the Coimbra identified collections, mainly from the Coimbra region, compiled as a Portuguese reference sample. Twenty-nine dental nonmetric traits were scored for Valença and Coimbra. Kendall's $\tau$-b correlations of FA and CFA results between traits were computed. After removal of correlated and problematic traits, percentages of FA, Comparable FA (CFA) (removing cases with bilateral trait absence) and Variation FA (VFA) (removing cases with lack of bilateral trait expression) were calculated. FA and CFA percentages were compared using Mann-Whitney U rank-sum test and z-ratio (difference of independent proportions test). Traits with strong ($\tau > 0.3$ or $\tau < -0.3$) significant correlations in FA presence were removed. Samples do not present significant difference in mean individual percentage for FA (VLN: 15.3%, COI: 12.3%; U=4226.5, p=0.560), CFA (VLN: 49.2%, COI: 44.6%; U=2503.5, p=0.612), or VFA (VLN: 54.9%%, COI: 40.5%; U=2299.5, p=0.110). Differences in asymmetry proportion were also not statistically distinct for CFA (VLN: 57.7%, COI: 43.9%; z=-1.408, p=0.1591). Yet, proportions differed significantly for FA (VLN: 16.9%, COI: 10.7%; z=-2.34, p=0.0193) and VFA (VLN: 58.6%, COI: 39.3%; z=-2.133, p=0.0346). FA levels suggest Valença suffered from greater levels of DI than Coimbra. Despite of the low socioeconomic status of both samples, Valença individuals possibly had lesser access to adequate nutrition and healthcare due to Valença's rural and peripheral location.

**Keywords:** Bioarchaeology, Nutrition and healthcare during development, Nonmetric dental traits, Modern and Contemporary Portugal, Rural and peripheral town

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# Dental restoration in past populations: a study case from Travanca's Church Cemetery (Santa Maria da Feira, Portugal)

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During the archaeological intervention of the cemetery of the Paroquial Church of Travanca (Santa Maria da Feira, Portugal), 412 graves, 47 ossuaries and more than 1000 isolated bones were unearthed. These graves were dated to the Medieval period until early 20th century, but only Post-Medieval graves conserved human osteological remains. Among the recovered human remains, the unusual dental treatment of a modern adult male exhumed from the churchyard stands out. This include restorations and treatments with the use of gold, found in the upper central incisors and canines. A black amalgam was also detected in the lower left and right first and second molars. This work examines the observed dental restorations, including a review of the medical and historical literature as an attempt to better document and interpret this practice, including insights of oral health and socio-economic status of this individual.

**Keywords:** Dental restoration, gold, black amalgam, adult male individual, Portugal

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# Teeth, paleodemography and paleopathology: a cementochronology analysis of the Medieval site of La Granede, France

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The medieval site of La Granede in southern France (AD400-1300) is a remote, low-density, rural community. Careful characterization of the archaeological context included the entirety of the funerary area, which remained undisturbed since its abandonment. Excavations revealed well-preserved skeletons (n=160), with a proportionate sex ratio and an equal number of adults and subadults. Recent methodological developments in cementochronology, the use of dental cementum annual growth patterns for individual age-at-death estimation, allow greater specificity and reliability in the estimation of age structure in archaeological samples. In addition, the completion of a new Bayesian inference procedure developed to estimate collective age offers a valid way to cross check estimated age structures using an alternative reliable dataset. This study compares adult age-at-death distributions and demographic parameters obtained through individual cementochronology methods and collective Bayesian techniques. We then contextualize adult dental and skeletal pathological data by age distribution to characterize the health of our sample. Age structures were based on 46 individuals scored for cranial suture and 60 teeth were extracted for cementum analysis. All adults were analyzed for dental and skeletal pathological lesions. The age structures obtained were comparable with a unimodal mortality peak centered on the 50-69-year age category. Pathological results revealed no metabolic lesions, limited signs of infection or inflammation, moderate frequencies of non-specific stress markers and a high presence of activity-related changes in both sexes. Dental pathologies also revealed a pattern consistent with an older population. Demographic and pathological results are concordant with a low-density rural community with attritional preindustrial mortality and typical lesions of agrarian or artisan occupations. Results support the renewed analyses of paleodemographic studies with new and valid tools to explore various archaeological contexts.

**Keywords:** cementochronology paleodemography paleopathology cementum medieval

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# Assessing human settlement dynamics in West-Central Mesoamerica through dental morphological and metrical variation: preliminary results

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West-Central Mesoamerica displayed changing and intricate cultural patterns through time. This cultural diversity is thought to reflect the settlement dynamics that occurred since the Preclassic period (600 B.C. - 200 A.D.) until the Conquest (1521 A.D.). Previous studies have shown that dental morphology and metrics are reliable proxies for reconstructing population history and enabling us to shed light on past settlement dynamics. The present multi-proxy study is trying to evaluate to which extent dental record may help us to highlight population movements in West-Central Mesoamerica and then identify causes of emergence of various cultural entities along periods. This work aims to explore dental phenotypic affinities between three distinct chronological groups of individuals: a Preclassic one (600 B.C. - 200 A.D.), a Classic-Epiclassic one (200 A.D. - 900 A.D.) and a Postclassic one (900 – 1521 A.D.). Here, we considered an adult sample from the actual Guanajuato and Michoacan states. The morphological and metrical investigations were based both on virtual and physical records. First, non-metric traits and linear measurements were recorded directly from dental remains. Secondly, we explored dental tissues proportions and enamel thickness using high-resolution computed tomography (microCT). Segmentation process of microtomographic data enabled us to reconstruct the enamel-dentine junction and evaluate, along periods, its shape changes through geometric morphometrics. Results suggest that differences between chronological groups exist. Nevertheless, we observed discrepancies regarding the signals expressed by dental morphology and dental metrics. Explanations for those results will be discussed and interpreted in light of archaeological contexts. They will give us a more accurate outlook on human settlement processes across the region.

**Keywords:** Dental morphology, Dental metrics, Mesoamerican dynamics settlements, Geometric Morphometrics

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# Dental health in Late Antiquity: comparison between the sites of Cortijo Nuevo and Cortijo Coracho Lucena, Cordoba, España

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The sites of Cortijo Nuevo and Cortijo Coracho were excavated in 2000/1 and 2003 respectively, with parts of their necropolises, both dating from Late Antiquity. Cortijo Nuevo has a smaller sample size and is associated to an agricultural oriented settlement, such as the villa type (4th and 5th centuries AD). Cortijo Coracho is a large necropolis with ad santos burials and surrounds a martirial basilica built in the 4th century AD which also includes Byzantine and Visigoth phases. Both sites contain inhumations but Coracho also includes a structure associated with ustrium like cremations with grave goods. In this project the focus is on the dental health of these populations, investigating dental disease, trauma and malformations. More specifically it has been assessed dental caries, calculus, abscesses, stulae, dental wear and dental and skeletal traumatic and congenital malformations. It has been reported on the results of a comparative study based upon the two sites in which has been assessed whether there are diachronic changes in health status.

**Keywords:** Paleodontology, dental diseases, physical anthropology, funerary archaeology, dental pathology

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# Cementochronological analysis in zooarchaeology: a new analytical protocol

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Seasonal variations and changes in environmental conditions directly impacted social and economic activities of past human populations. Among various approaches, cementochronology has been developed to tackle such questions. It relies on the study of the dynamic patterns and rhythmicity in the deposition rate of the dental cementum observed under microscope after the realization of petrographic thin-sections within teeth found in archaeological contexts. Cementum growth follows predictable seasonal cycles with an alternation of fast and slow rate deposits during respectively growth and non-growth seasons. The outermost increment, forming at the time of death, is expected to give reliable estimation of the season at death. However, while archaeologists have used this method for the past fty years, no protocol of analysis, including the definition of acceptation of a specific Region of Interest (ROI) and the decision process in the identification of the last increment, has been published. Based on the confrontation of experiments of specialists from different archeological fields (past wildlife predation, domestication, human burials), biological and optical criteria have been identified for the selection of ROI and for their analysis. This protocol has then been applied through a blind-test performed by very different analysts with different skill levels. Thirty thin-sections of modern reindeer teeth from a comparative collection with known age and season at death were selected. Observations were conducted under the same microscope. For each observer, number of selected ROI, their localizations, their pictures were recorded, and their analyses were then compared. The results demonstrate here the accuracy of this new protocol and its replicability. They also underline the impact of experience in the decision process for the acceptation or the reject of a ROI.

**Keywords:** Cementum, tooth, seasonality, blind test, archaeology

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# Neanderthal hunting seasonality and mobility patterns: a cementochronoligical approach

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The late Middle Paleolithic in Southwestern Europe is characterized by major climatic fluctuations that had a direct impact on Neanderthal ecosystems. Sedentary and migratory ungulate populations alternated in the environment. Neanderthal hunter-gatherers, were forced to adapt their mobility to the migration pattern of their prey, conducting to a reorganization of the activities within their territories in function of the seasonal cycle. In this context, seasonality is a key topic for the reconstruction and understanding of the subsistence systems and settlement patterns developed by these human communities. We proposed here a regional synthesis of seasonal data based on published and unpublished cementochronological analyses of late Middle Paleolithic sites from Southwestern France. Cementochronology relies on the study under microscopic cross polarized light of the dynamic patterns and rhythmicity in the deposition rate of a mineralized tissue, the cementum, around the tooth roots. The cementum growth follows predictable seasonal cycles with an alternation of fast and slow rate deposits during respectively the good and poor seasons. The outermost increment, forming at the time of death, is expected to give precise estimation of the season at death. Ungulate teeth from sites attributed to the MIS 4 and 3 with available zooarchaeological data were selected. The sampling was based on the MNI and postmortem modifications were systematically looked for. The results were then compared to comparative collection prior being interpreted in term of season of death. Our study shows that the different Neanderthal populations developed specialized strategies to cope with the seasonal uctuation of their prey. Innovative hunting strategies were established as a response to the ethological specificity of their games conducting to the reorganization of human settlement dynamics.

**Keywords:** Mousterian, zooarchaeology, cementum, season, mobility

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# Exploring past exchange networks and symbolic hunting through the study of mammal teeth beads

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The Große Ofnet head burials (Germany) have been interpreted as evidence of interpersonal violence within the last Mesolithic societies of Western Europe. A large number of perforated red deer canines (n=217) were discovered in the grave, some of them still positioned on the frontal bone of the individuals buried in the cave. This study aims to characterize mobility and territoriality of the last hunter-gatherers, in order to understand their social organization. We submit the perforated red deer canines associated with the head burial to taphonomic, archaeozoological, technological, morphometric, and functional analyses in the aim to document the variability in raw material procurement, bead manufacture and duration of use. Our results indicate complex acquisition patterns of the ornaments, including multidirectional exchange networks. Homogeneity in the bead manufacture suggests contacts between contemporaneous groups that shared the same technical traditions. We conclude that the last Swabian Mesolithic groups maintained active networks by perpetuating exchanges across large areas. Previous works have interpreted hostile intergroup relationship as evidence of a decrease in their mobility. Our results highlight that, in the case of Ofnet, such a reduction in mobility can be largely counterbalanced by the perpetuation of large-scale exchange networks. This study, based on modern reference collections of red deer canines, illustrates the ability of personal ornaments made of mammal teeth to document large exchange networks.

**Keywords:** Morphometry, red deer, mesolithic, personal ornaments

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# Dental micro- and mesowear as high-resolution proxies for the study of ungulate diet and its relation to the human occupation patterns at Divnogor'ye 9 (Late Pleistocene, Russia)

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Dental wear refers to two methods for reconstructing dietary habits in ungulates. They correspond to two scales of analysis, macroscopic (mesowear) and microscopic (microwear), which are related to different temporal scales. Consequently, each method is giving access to very different periods in the life history. Mesowear is a proxy averaging diet over months while microwear reflect the diet of the last days before death. In this study, we present the results of mesowear and microwear analyses on the horse fossil populations recovered in two archaeological levels at Divnogor'ye 9 (Late Pleistocene, Middle Don drainage basin, Russia). The first objective is to integrate the results from mesowear and microwear to provide indirect evidence of the dietary habits of the horse (*Equus ferus*) and to reconstruct their habitat(s). The second objective is to use tooth microwear patterns (microscopic features produced by food items on teeth) as a high-resolution proxy for estimating the duration of mortality events and their seasonality. Regarding the dietary habits of the horse, both mesowear and microwear classify the two assemblages in the grass-dominated feeding category. The study of the horse mortality events provides significant information about seasonal resource procurement by hominins. A new tool of microwear analysis permitted to classify the two assemblages as seasonal events. The results are thus confirming the accumulation of the horse remains at the site during seasonal repeated occupations of the site. This technique opens new perspectives to investigate seasonal patterns of ungulate accumulations in archaeological sites using non-destructive sampling.

**Keywords:** microwear, mesowear, seasonality, ungulate, zooarchaeology

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# What teeth can tell us about agricultural transitions on the coast: a case study from the prehistoric Baltics

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Ancient Baltic communities underwent a unique transition into agriculture, as they lived on the coast with access to ample amounts of freshwater and marine food resources (e.g., waterfowl, water-based plants, fish and shell fish). The ways in which people have adapted to coastal environments, and to changing technologies and subsistence patterns within such habitats, are still not fully understood. The Baltic situation is special as recent research has shown genetic continuity between Mesolithic and Neolithic populations, rendering it difficult to say when the 'first farming' began. We studied cranial and mandibular shape and size, as well as tooth size and dental pathologies, in over 150 individuals dated between the Baltic Mesolithic period and Late Iron Age (11th millennium BC - 1st century AD). These osteological and dental remains derive from Stone Age and metallurgic Estonia and Latvia, with all skeletons included in the sample being adults. First, craniofacial and mandibular robusticity, in addition to tooth crown size, were measured to further understandings of the skull's plastic responses to dietary changes. Our results show a predicted reduction in cranial, facial and dental dimensions in the populations as agriculture was more widely practiced. Second, recording the rates of dental pathologies (e.g., caries, periapical lesions, calculus, periodontal disease, and tooth loss), and tooth enamel defects (i.e., linear enamel hypoplasia) allowed for the evaluation of general health levels and the quality of diet among these ancient Balts. Observed dental pathologies revealed various significant patterns indicative of the types and quality of food these settlements were feeding on. In conclusion, coastal communities are understudied in archaeological scholarship when compared to that performed on inland populations. Overall, this research aims to address this imbalance by contributing the unique coastal experience of prehistoric Balts to greater understandings of subsistence-related behavioural and biological change worldwide.

**Keywords:** caries, calculus, tooth size, palaeopathology, Baltics

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# Sexual dimorphism in dental cementum microstructure: applications for sexing in archaeological modern human and Neanderthal remains

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Cementum, the connective tissue that anchors mammalian teeth within the alveolar socket, grows continuously and with an annual rhythm; it is recorded by a series of circum-annual increments of contrasting opacity when viewed under light microscopy, with hyper-mineralized increments recording a reduction of growth rates. The objectives of this project are to use high-resolution synchrotron-based radiation tomography (SRCT) to test whether the microstructure of cementum is sexually dimorphic in archaeological modern human and Neanderthal remains. A sample of both physically down-sampled teeth and entire teeth was taken from archaeological skeletons of known identity, and from archaeological skeletons of unknown identity, from Bristol and Taunton (SW UK). 4 whole teeth were also studied from a collection of disarticulated Neanderthal remains from Sirogne (SW France). The roots were scanned at the Swiss Light Source on the TOMCAT beamline using a suite of novel parameters designed to optimize image quality in both down-sampled and whole teeth. Reconstructions employed exploratory phase-contrast enhancement ("Paganin-style") algorithms. Reconstructed scans were analysed using commercial software (Avizo, Fiji). Following validation experiments on a controlled, sexed macaque sample (also presented at ISDM, in Newham et al), quantitative morphometric techniques were applied to assess variation in 3D microstructure between increments (tortuosity, 3D texture, cellular voids) formed in each individual specimen. Principal Component Analysis of these 3D microstructural data demonstrates that male cementum increments are relatively homogenous and have low microstructural variance, while female increments are significantly more tortuous and varied. These characteristics may reflect hormonal cycling and the impact of pregnancy. This methodology therefore has potential not only as a tool for sexing and assessing signatures of life history of individuals in forensic, anthropological and archaeological contexts, but also as a means of enriching our understanding of life history in fossil species.

**Keywords:** Cementum, life history, sexual dimorphism, tomography, human

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# Demographic and paleopathological study from Sardinian dental remains

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The purpose of this study is to reconstruct the demographic and palaeopathological characteristics of individuals based on a sample of mandibular and maxillary dental remains, found both in situ and ex situ, from an archaeological excavation located in the North-Central Sardinia, dating between the ninth and second centuries B.C. The analysed sample is constituted by 220 adult dentitions and 55 sub-adult dentitions, each of which has been identified and lateralized. The biological age-at-death was estimated through dental eruption patterns and performing an evaluation of root development in sub-adults, and examining dental wear in adults. Metric and morphological dental analysis were performed, recording every epigenetic and pathological evidence so to provide a general framework for the local population and reconstruct the features of the odonto-stomatognathic functional system. In addition, alterations due to contextual taphonomy, which might have influenced this sample completeness, were observed. The analysis performed show a low incidence of dental diseases, usually due to poor hygiene, diet and genetic issues, metabolic disorders (few cases related to hypoplasia) and epigenetic issues. We also found some interesting dental wear patterns that do not seem to correspond to the diet-related affection because of their angles and positions. Considering the odonto-stomatognathic system of this sample the overall framework shows a population in good health conditions. Moreover, the wear patterns indicate functional aspects of teeth, other than chewing food, in this sample.

**Keywords:** teeth, taphonomy, paleopathology, Sardinia, anthropology

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# A previously unnoticed Neandertal dental autapomorphy?

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Due to being the sturdiest elements of the skeleton, teeth preserve better than bones and dental material is overwhelmingly the most represented in the fossil record. Identifying dental autapomorphies is thus of the uttermost importance in paleoanthropology in order to assign a taxonomic status to even fragmentary material and discuss their phylogenetic relationships. Here, we present a dental trait that we have observed only on Neandertal crowns. Externally, it is an oval-shaped fossa in the enamel of the upper lateral incisors' labial surface. The long axis of the fossa is oblique and runs supero-mesially to infero-distally. It may be present bilaterally when both upper lateral incisors of an individual are preserved. No other tooth type has been observed showing a similar fossa. The upper lateral incisor fossa is different from a hypoplastic defect in that a corresponding fossa is also present on the surface of the enamel-dentine junction as observed on microCT images. Upper lateral incisor fossae have been noted in about half of our Neandertal dental sample, and they are present over both a long period of time and extended territory since we observed fossae in early Neandertals, such as Biache-Saint-Vaast 1 (N France), as well as late Neandertals, such as Vindija 289 (Croatia). We will discuss the factors that may underlie the development of such a feature in the crowns of Neandertal upper lateral incisors.

**Keywords:** paleoanthropology, autapomorphy, Neandertal, upper lateral incisor, labial fossa

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# An innovative approach to Neanderthal occupational patterns by integrating dental wear and cementochronology. Case studies of Cova de les Teixoneres and Cueva de Covalejos (Iberian Peninsula)

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To identify the occupational patterns developed by Neanderthal groups, the key is to understand their behavioral and subsistence strategies. Prey ecology and behavior that have direct effect in human behavior, are influenced by changes in the environment. Therefore, the prey's paleodiet allows to assess seasonal changes that occurred throughout the year in the environment of a given site. For the first time applied to archaeological contexts, we propose a combined analysis of dental wear (meso- and microwear) and dental cementochronology methods on ungulates molars (*Cervus elaphus, Equus ferus, Bos/Bison*). Dental wear methods (non-destructive) are based on the assumption of changes in the resources that are consumed over time (throughout the year). Dental meso- and microwear reflect the immediate behavior of the ungulates as well as the environmental conditions around the site. They allow to estimate the relative duration of the accumulation of preys at the site. Cementochronology (partially destructive method) relies on the analysis on dental seasonal increments within the cementum. It is expected to provide the age and season of the individual death, allowing to accurately identify the seasonality of Neanderthal contribution to the archaeological sites and the procurement strategies. In this research, this approach was developed for two Middle Paleolithic sites of the Iberian Peninsula: Cova de les Teixoneres (Moia, Barcelona) and Cueva de Covalejos (Pielagos, Cantabria). We identified a pattern of occupation based on a sequence of repeated use of the caves at different seasons throughout the two sequences at the exception of however; Covalejos level H that attests of a short seasonal occupation. This innovative combined method allows not only to identify the relative duration of the Neanderthal occupations, but also to replace their behavior in the annual cycle.

**Keywords:** Dental wear methods, Cementochronology, Neanderthal Occupational patterns, Multiproxy approach, Iberian Peninsula

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# Dietary inferences of the Chalcolithic population from El Portalon de Cueva Mayor (Sierra de Atapuerca, Burgos)

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Dental microwear analyses have proved to be a useful technique to characterize subsistence strategies in both prehistoric and recent humans. The analysis of microwear patterns can be carried out through the study of occlusal or buccal surfaces, but recent studies have demonstrated that the application of these two kind of analysis in the same specimens not only offer consistent results, but also allow us to obtain more complete dietary inferences. In this sense, the main goal of this study is to make dietary inferences through dental microwear pattern on buccal and occlusal surfaces of the individuals from the Chalcolithic levels of El Portalon de Cueva Mayor (Sierra de Atapuerca, Burgos). A total of 21 teeth, both permanent and decidual, belonging to a minimum of seven individuals have been studied. For comparative purposes of different environments, we have also analyzed an unpublished coetaneous sample of six teeth from the Northern Iberia (La Huesera, Alava) and we used the published data on the Neolithic individuals from the Mediterranean coast (Tossal de les Basses, Alicante). Pattern of microwear on buccal surface was established in incisors and molars taking linear and angular measurements of the scratches. In the case of occlusal surface, microwear features (both scratches and pits) of incisors and molars were counted and measured. Our results indicate a mixed diet for Chalcolithic individuals from both El Portalon and La Huesera with a high consumption of meat. These findings contrast with those present in individuals from Tossal de les Basses, whose diet was mainly based on vegetable resources. These differences can be due to a higher dependence on animal husbandry of individuals from El Portalon and La Huesera related to environmental conditions.

**Keywords:** Chalcolithic, diet, microwear

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# Estimating stable carbon and nitrogen isotope compositions from dental calculus: from serendipity to synthesis

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In 2011, when attempts to extract phytoliths from the dental calculus of medieval and post-medieval Basques met with limited success, we took 58 calculus samples and ran them through a mass spectrometer to see what would happen. Somewhat surprisingly, there was sufficient carbon and nitrogen to get estimates of 13C and 15N that corresponded closely with collagen-based results from a wide range of European samples. This led to the initial publication on calculus and isotopes in the Journal of Archaeological Science in 2012. Thereafter, we directly and indirectly (through the aid of colleagues around the world) obtained calculus samples from skeletal remains in Chile, Peru, Colombia, Mexico, Belize, Portugal, England, Greenland (Inuit and Norse), Iceland, and Palau, along with living individuals from Reno, Nevada. While correlations between isotopes derived from calculus and proteins (e.g., collagen, keratin) are often non-significant, the 15N values from calculus yield mean values consistent with other biomaterials while 13C is often 2-4 lighter. Calculus, not surprisingly, shows more within group variance than other biomaterials given that it is not a protein and derives nitrogen and especially carbon from a variety of sources. Although calculus in no ways usurps the role of collagen in isotope studies of prehistoric populations, it does have two advantages. First, sample preparation is much easier and straightforward than the procedures required for collagen. Second, as an add-on, the use of calculus is technically non-destructive as it is not part of the skeletal or dental system.

**Keywords:** calculus, stable isotopes, carbon, nitrogen

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# Tooth wear and evidence of non-masticatory dental use in Late Neolithic Age individuals exhumed from the artificial cave of Bautas (Lisbon, Portugal)

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Recent reanalysis of the human remains unearthed from the artificial cave of Bautas (Lisbon, Portugal), involved the analysis of tooth wear patterns and non-masticatory behaviour of these Late Neolithic individuals. Presently, the human bones recovered from this hypogeum are curated in the National Museum of Archaeology (Lisbon) and consists of a commingled bones assemblage. The reassessment of the osteological collection revealed a provisional minimal number of 38 individuals. This assemblage included mainly as isolated teeth. In total, around 950 teeth were analysed. Dental wear, oral lesions (chipping and grooves) and enamel hypoplasia were assessed. Here we discuss the results of the dental analysis in terms of dietary and non-dietary behaviour corresponding to the daily activities of these prehistoric individuals.

**Keywords:** Tooth wear patterns, Non, masticatory dental use, enamel defects, Late Neolithic, Portugal

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# Analysis of dental pathologies and stress indicators in a human sample from the Medieval cemetery of Jesolo Le Mure-Venice, Italy

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The archaeological investigations in the site of Jesolo-Le Mure allowed the excavation of an early medieval cemetery, connected to an earlier church found under the XIIth century cathedral, where 66 burials have been brought to light and dated approximately to VI-VIIth century AD. The ancient settlement of *Equilo*, during the Roman age and the Middle Ages was a island in the lagoon that nowadays surrounds Venice. Human skeletal remains have been studied from a palaeobiological and paleopathological perspective: diagnosis of sex and age at death of the individuals and paleodemography of the population, metrical and morphometrical evaluation of the sample, assessment of the frequency of discontinuous traits and markers of occupational stress, skeletal and dental pathological records. Teeth were preserved in almost each adult and juvenile subject and have been examined to evaluate the presence of calculus, caries, tooth losses during lifetime and other dental stress marker such as enamel hypoplasia lines. The frequency of these pathologies has been related to age classes (diagnosed also by Cameriere's radiographic method) and to the presence of other skeletal markers of stress in order to evaluate the health status and lifestyle of this population and to compare it to other Middle Age human groups currently under study by the Physical Anthropology Laboratory of Ca' Foscari University-Venice. The frequency of enamel defects has been evaluated and related to the age at death of the samples, either in young individuals deceased before reaching adulthood and succumbed to critical conditions, and in adult subjects that indeed survived the critical stages of childhood, with the aim of better understanding episodes of nutritional stress or pathological disturbances testified by skeletal remains.

**Keywords:** palaeobiology, teeth, Middle Age, Northern Italy, human skeletal remains

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# Dentition of the Hun Warrior from Ptuj (Slovenia)

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In 2000, during the excavation of the Late Antique necropolis in Ptuj (eastern Slovenia) archaeologists under the direction of M. Lubsina Tusek discovered an almost complete skeleton of a young male with artificially deformed skull. The grave goods were represented by gilded bronze earring, parts of belt set, coin, arrowhead, and iron sword. They indicate that the deceased was a member of the Hun tribes from the middle of the 5th century AD. This grave is the first material trace of the Huns on the territory of Slovenia. Anthropological analysis of the skeleton made by P. Leben Seljak revealed that he died in his early twenties. The method of Kvaal et al. (1995) based on dental radiographs arrived at age estimate of 20.80 years. Mongoloid anthroposcopic features of the skull (unmarked masculine sexual traits, rounded orbits, broad zygomatic bones with inferior zygomatic projection, wide ramus of mandible, and elliptic palate with straight palatal suture) as well as small body height (around 163 cm) and relatively gracile body composition indicate Asiatic ancestry of the deceased. Artificial cranial deformation is of so-called fronto-occipital type caused by head-binding during childhood. The dentition shows slight occlusal attrition and peculiar approximal grooves on maxillary incisors. Their formation could be explained by repeatedly dragging sinews between incisors during the process of making bowstrings. The dentition is without pathological lesions. The tooth crown morphology is complex (moderate UI shoveling, UM1 and UM2 C5, LM1 C6, LM2 C5, UM and LM enamel extensions); however, the root morphology is simplified (27 single-rooted teeth out of 32). The computer application rASUDAS was used for dental ancestry assessment. The deceased was assigned to American Arctic & Northeast Asia with the highest posterior probability (87.52%) followed by East Asia (12.47%). Western Eurasian ethnic origin was almost completely excluded (0.01%).

**Keywords:** paleodontology, dental morphology, ancestry, Huns, Slovenia

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# The Muddle in the Middle? Characterising population diversity in coastal Central Peru in the Prehispanic Period, using dental non-metric traits

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Previous studies of archaeological/ethnographic evidence have claimed that the Prehispanic Central Coast of Peru was characterised by dynamic population movements and migrations. However, the nature of the evidence is ambiguous at best. It was therefore posited that bioarchaeological methods specifically dental anthropology could assist in this debate. In order to assess this, 173 individuals from 4 different groups were analysed using 20 dental non-metric traits as defined by the ASUDAS (Arizona State University Dental Anthropology System). The groups were selected to represent the full (c.1600 year) chronological range of Central Coast occupation: a Pre-Lima group (Tablada de Lurín, n=25), a Lima group (two pooled sites from the same period [Huaca Pucllana n=10; Huaca 20 n= 50]), an Ychsma group (Pachacamac, n=51) and an Inca group (Pueblo Viejo-Pucara, n=37). Twenty traits were scored across all groups in order to establish affinities and group characterisation through descriptive (frequencies) and multivariate statistics (Principal Components Analysis, multidimensional scaling and cluster analysis). The results demonstrate that dental morphology can be used to chart temporal fluctuations in biological affinity in the same geographical area. On the basis of this study, it is apparent that there was biological continuity between the Pre-Lima, Lima and Ychsma, and a discontinuity between these three and the Inca group. The implications of these findings are discussed in the context of relevant archaeological and historical research.

**Keywords:** Dental morphology, ASUDAS, Andean archaeology, Andean archeology, dental non-metric traits, teeth, Inca, Andes, South America, Peru, dental anthropology

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# Periodontal disease, aetiology, biological processes and its connection to diet and dietary consistency: a case study from Medieval Sudan

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Despite extensive research on the aetiology of periodontal disease in living patients, the condition has proved difficult to study in the dry bone of archaeological jaws. In particular, tooth loss due to periodontal disease can often not be distinguished from that of extraction, heavy wear and continuous eruption. This study observes differences in the prevalence of periodontal disease in conjunction with the prevalence of root surface and interproximal caries, in an attempt to better understand their association and create a framework for interpreting periodontal disease in archaeological assemblages. Sites 3-J-23 (AD600-1000) and 3-J-18 (AD1000-1500) from the 4th Cataract, Sudan, were used as a case study. Results demonstrated that 3-J-23 had a significantly higher prevalence (p=0.0001) of periodontal disease and dental caries than 3-J-18. Males showed a statistically higher prevalence of periodontal disease than females at both sites (p=0.0001/p=0.0004). Females at 3-J-23 had a statistically higher prevalence of caries at all locations when compared with males. At 3-J-18, although females had a higher caries prevalence than males, only interproximal root and facet caries were significantly different. Dental caries is intimately linked with the carbohydrate intake of a population. These results suggest a difference in diet between the two sites and the sexes, which could represent a higher carbohydrate intake in females and during the earlier Medieval period. The higher prevalence of periodontal disease at 3-J-23 may indicate large plaque deposits between the teeth, perhaps suggesting that dietary carbohydrates were of a sticky consistency. Interestingly, evidence of possible oral hygiene in the form of non-masticatory interproximal and buccal grooving was found more commonly in 3-J-18 than 3-J-23. This may help to explain the lower prevalence of periodontal disease at this site. Comparison of periodontal disease with dental caries highlights their association, giving unique insights into dietary behaviour in Medieval Sudan.

**Keywords:** Dental Anthropology, Periodontal Disease, Dental Caries, Sudan, Archaeology

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# Complex type enamel hypoplasia in human permanent canines from a mass fatality in an early urban center in Syria

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Generally, three basic types (pit-, furrow-, and plane-type defects) of dental enamel hypoplasia are distinguished. Defect types vary according to ameloblast related factors (ameloblast age and stage of secretory activity) and stress related factors (impact intensity and duration). More complex forms of enamel hypoplasia, characterized by highly irregular enamel morphology and considerable extension along the corono-cervical crown axis, have been described; however, their formative mechanisms have remained largely unexplored. Here we report multiple cases of complex hypoplastic enamel defects in human permanent canines from Tell Majnuna, a site located near Tell Brak, a major urban centre of the Late Chalcolithic in Syria. In a midden dated to 3750-3500 cal BC human mass burials were found including one cluster that contained disarticulated and scavenged bones of mainly females, children and adolescents. Axiobuccolingual ground sections of the teeth were examined by light microscopy. The enamel defects presented as extended areas with abnormally thin enamel. In the affected crown portions, striae of Retzius originated more or less perpendicular to the enamel-dentine junction followed by an upward bending more peripherally. In the defect areas, enamel prisms were inclined cervically and the reconstructed enamel extension was low (< 4 m per day). This is seen as indicative of a lower than normal rate of recruitment of presecretory ameloblasts into the enamel forming front. The archeological context, high degree of scavenging, sex and age-at-death bias in the assemblage, signs of inter-personal violence in the remains, in combination with 18O data suggest a long-lasting environmental and related social crisis. The inferred prolonged stress period is seen as the cause of the recorded complex type of enamel hypoplasia being the consequence of a reduced rate of ameloblast differentiation.

**Keywords:** complex enamel hypoplasia, bioarchaeology, enamel extension rate, einvironmental crisis

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# 3. Dental growth and development

# Dental developmental pattern and tooth internal structure in the Neanderthal child Châteauneuf 2 (Hauteroche, Charente, France)

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Differences have been reported between Neanderthals and recent humans in their pattern of dental development and internal tooth structure. Compared to recent humans, Neanderthals show an early development of the molars relative to that of the incisors and first premolars, larger tooth volume at each position but with a mesio-distal decrease along the arcade, similar enamel but larger dentine volumes in their deciduous and permanent teeth. However, few complete dentitions have been published for their tissue proportions, and little quantitative information is available on anterior teeth. Furthermore, how dental maturational patterns and metameric variation in tissue proportions along the arcade are linked together has been poorly investigated. Here we used microCT-based data, as well as radiographic and CT records, to finely quantify these variables in the deciduous and permanent teeth of the Neanderthal child Châteauneuf 2 from Hauteroche (Charente, France), and compare the measures to other Neanderthals and to Late Pleistocene and Holocene modern humans of worldwide origins. Like other Neanderthals and the Gravettian child from Lagar Velho, Châteauneuf 2 shows an advancement of its first molar development compared to later Pleistocene and Holocene individuals. While the Châteauneuf 2 internal tooth structure is in line with the Neanderthal range of variation for deciduous teeth, it extends the range of variation known hitherto for the first permanent molar. Furthermore, Châteauneuf 2 fits the Neanderthal pattern by having particularly large incisor dentine volumes and high metameric variation. Our results suggest that Neanderthal intra- and inter-population variation in internal dental structure is still far from having been fully documented. Even if future investigations are needed to unlock the genetically- and/or functionally-related factors sustaining these observations, the relative anterior versus posterior developmental stages in Neanderthals may result from volumetric and tissue proportional differences between anterior and posterior teeth compared to those of recent humans.

**Keywords:** dental development, internal tooth structure, metameric variation, Neanderthals, modern humans

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# Incremental enamel growth of Natufian deciduous teeth from Shubayqa, Jordan

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Recent excavations at Shubayqa 1, the first well-dated Natufian site outside the traditionally termed 'core Mediterranean zone', in the northern Badia region of eastern Jordan, have recovered the remains of a minimum number of 23 individuals. This sample includes six perinatal remains, revealing an untypical profile of a (Natufian) burial environment and providing an excellent opportunity for an in-depth study of human growth and deciduous dental development. The aim of the present study is twofold: 1) to compare metrical features of skeletal and dental development with the results of the microscopic approach of age-at-death estimation based on the neonatal line 2) to compare the enamel secretion rates between individuals from this unique archaeological context and with the published literature. Longitudinal ground sections of ten deciduous teeth were selected that showed clearly visible daily enamel cross striations in the pre and postnatal enamel of the occlusal, lateral and cervical regions of each tooth. The presence of a neonatal line was established for all cases, indicating birth survival of all six perinatal individuals. Histological ages assessed by counting prism cross-striations external to the neonatal line, range from less than 2 to 27 postnatal weeks. Age estimations based on tooth measurements and corresponding regression formulae range from 36 weeks gestational age to 26 postnatal weeks. In addition, accentuated striae were observed in prenatal enamel, suggesting stress episodes during fetal life. New data is provided on deciduous enamel secretion rates in modern humans from Southwest Asia.

**Keywords:** Enamel, neonatal line, incremental markings, age estimation, bioarcheology

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# New data on developmental sequences in the dentitions of the Euarchonta

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It has long been recognized that the sequence of tooth eruption reveals the pace of life history in primates, but micro-CT analyses also demonstrate that the relative state of development of the dentition before eruption reveals important information. Here we present the developmental sequences of several euarchontans, the Paleocene-Eocene taxon *Plesiadapis*, the two genera of colugos, *Galeopterus* and *Cynocephalus*, the tree shrews *Ptilocercus*, hypothesized to be the most primitive of the extant genera, and data on the poorly known *Urogale* and *Dendrogale*. In all taxa, molars erupt before the replacement dentition, following Schult' rule for animals with a rapid life history, but in *Ptilocercus*, both the eruption and the developmental sequence differ in the maxilla and the mandible. In the maxilla, the P4 develops and erupts before the P2 or P3, while in the mandible, the P4 is the last premolar to develop and erupt. In the mandible, the large procumbent incisors begin to develop before the M3 has erupted, although they are the last permanent teeth to erupt. In *Plesiadapis*, the P3 erupts before the P4, and both after the molars, but with almost no root development, which may be due to the extremely large developing procumbent incisor. Interestingly, colugos show relatively slow dental development compared to the other taxa, with less premolar development at similar stages of molar eruption, while the large mandibular incisors, each one shaped like a comb, also begin to develop early and erupt late. The eruption sequences differ in the maxilla and the mandible and between the taxa. While life history plays a role in dental development, the presence of complex or procumbent incisors also affects premolar development and eruption, suggesting that studies of dental eruption in those taxa with this morphology should include both mandibular and maxillary dentitions before making life history inferences.

**Keywords:** tooth eruption, life history, premolar sequence, microCT, morphology

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# A radiographic study of root resorption of mandibular deciduous molars

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The position of the developing premolar crown growth and eruption influences the pattern of resorption of mesial and distal roots of the mandibular deciduous molars. The aim of this study was to compare the resorption levels of the mesial and distal roots of the mandibular deciduous molars from a large radiographic sample of dental patients. This was a mixed-longitudinal archived sample of dental panoramic radiographs from 830 individuals aged 2-15 years of age. Both roots of the mandibular left deciduous molars were scored into five categories (no resorption, 1 to 4 quarter fractions). We compared resorption in the mesial with the distal root in both first and second molars. We calculated the frequency of cases with similar levels of resorption, mesial root more resorbed and the distal root more resorbed. Results show that both roots were scored in 611 first molars and 873 second molars. In first molars, 70% of cases resorption levels were similar between roots compared with the distal root more than mesial in 22% of cases. In second molars 67% of cases showed similar root resorption with mesial root more resorbed in 22% compared with 11% distal root more resorbed. These findings suggest that there is considerable variation in the pattern of root resorption in mandibular deciduous molars. If resorption levels differed in roots, the distal root of the first molar and the mesial root of the second molar were more frequently observed at a further level of root resorption than the adjacent root.

**Keywords:** deciduous, tooth, root, resorption, mandibular

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# Appearance of the neonatal line depends on gestational rather than delivery variables

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The factors underlying the appearance and formation of the neonatal line (NNL) in dental enamel have been vigorously debated since its identification. The size and visual appearance of the line in thin sections of deciduous dental enamel have been attributed to, variously: means of delivery, length of delivery, foetal distress (assessed as levels of metabolic disturbance, medical intervention, and other measures), gestational age, birth weight, sex, and even season of birth. This paper examines the appearance the NNL in a sample of 81 deciduous canines with detailed gestational and obstetric histories as part of a large medical cohort study. The results confirm the association of increased NNL width with gestational age at delivery and disturbances to the mother's metabolism during pregnancy. They do not support an association with method or length of delivery or variation between preterm infants of different sexes, and the association with seasonality is markedly different in this sample. The finding that hypertension in pregnancy is also associated with increased NNL width strongly supports a theory of NNL formation where contributing factors are those operating on the mother and foetus rather than reflecting circumstances of birth.

**Keywords:** Neonatal line, deciduous dentition, enamel development, microhistology

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# Patterns of correlation in growth as measured by tooth crown height and bone dimensions in a large assemblage of children's skeletons from an ancient cemetery on the island of Astypalaia in Greece

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Most of the 3000+ burials in the Kylindra cemetery on the island of Astypalaia date between 600 and 400 BC. All are of children buried in amphorae and were neonates or infants at the time of death. Although child burials in pots are a common finding in Classical Greek cemeteries, they are always mixed with adult burials. The size of Kylindra is unique in Greece and it may well be the largest ancient children's cemetery known anywhere. To date, our bioarchaeology project has recovered remains from 1500 burials. A large measurement database of developing tooth crown heights, lengths of long bones and dimensions of skull bones has been accumulated. We can use this to compare dental development with skeletal development during a phase of extremely rapid growth. From this it is possible to show that development is strongly correlated between anterior teeth and less so between anterior and cheek teeth. This may be due to morphological differences, but it may also be that earlier initiating teeth are less variable than later. Intercorrelations between developing heights of all teeth are, however, considerably higher than correlations between developing bone dimensions. There are also only modest correlations between bone and tooth measurements. This suggests a stronger patterning of dental development in comparison with skeletal development and shows how they unfold in very different ways.

**Keywords:** development dental skeletal

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# Mineral apposition rates in coronal dentin of mandibular first molars of Soay sheep - results of a fluorochrome labeling study

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We studied the spatiotemporal variation of mineral apposition rates (MARs) in postnatally formed coronal dentin of mandibular first molars of sheep that had been repeatedly injected with different fluorochromes over a maximum period of about 600 days. MARs showed a huge variation and a declining trend along the cuspal to cervical crown axis, and also with increasing secretory age of the odontoblasts. Highest MARs of about 21 m/day were recorded in cuspal dentin formed during the period of 28-42 days post partum. Lowest values (< 2 m/day) were recorded in late-formed (secondary) dentin close to the dentin-pulp-interface. The high MARs recorded in the dentin of the cuspal crown portions of sheep molars are interpreted as an adaptation to the necessity of forming a large, high-crowned tooth within a relatively short time span of less than one year. The established dentin MARs in the different crown portions of sheep molars will allow a rather precise timing of stress events affecting dentin formation, and also enable to reconstruct temporal variation of dentinal trace element uptake in sheep teeth.

**Keywords:** dentinogenesis, fluorochromes, intravital labeling, mineralization, teeth

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# Incremental markings in porcine enamel revisited: evidence for a daily periodicity of laminations in wild boar teeth

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Recently there have been conflicting statements regarding the periodicity of incremental markings in porcine enamel. While Kierdorf et al. (2014) reported the presence of laminations with a daily periodicity and of prism cross striations with a sub-daily periodicity in domestic pigs, these two types of incremental markings were characterized as long period (multidien) markings (striae of Retzius) with a five-day periodicity and daily prism cross striations by Bromage et al. (2016). The present study reports findings on incremental markings in the enamel of deciduous mandibular fourth premolars (dP4) and first molars (M1) from four wild boars. In the dP4, the median number (from multiple counts per tooth) of laminations external to the neonatal line (NNL) varied between 11 and 20 in the studied individuals. For the M1, the respective value ranged between 87 and 95. Based on known eruption times for these teeth (dP4 within the first month of life; M1 at about five months) and previous CT data on the timing of tooth crown formation in pigs, we conclude that our findings are supportive of a daily periodicity of the lamination-type incremental markings in wild boar enamel but inconsistent with the assumption of a five-day periodicity of these markings. The results of the present study underscore that laminations with a daily periodicity are the dominant internal incremental markings in porcine enamel, as is the case also in other ungulates. Interestingly, regular long period (multidien) markings are visible at the enamel surface of porcine teeth in the form of perikymata. It is hypothesized that the apparent lack or non-discriminability of internal long period markings is primarily related to the high apposition rate in porcine compared to primate enamel.

**Keywords:** enamel, incremental markings, laminations, perikymata, *Sus scrofa*

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# Biorhythm in deciduous molars from the Tooth Fairy collection: preliminary results

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One of the most important discoveries in evolutionary developmental biology in recent years is the link between microscopic evidence of a biorhythm retained in tooth enamel (termed Retzius periodicity), body mass, and the scheduling of life-history traits, when compared between primate species. In this study, we explore links between the biorhythm and growth within human children (boys and girls) between birth and the early childhood years. All children were part of the Tooth Fairy reference collection, which consists of deciduous teeth shed during childhood from individuals with known kinship and life-histories. First and second upper deciduous maxillary molars (n=32) from 19 individuals from the reference collection were selected for histological analyses. Thin sections were prepared, Retzius periodicity and daily enamel secretion rates were calculated for each section. These variables were compared to each child's birth weight and height, and body mass trajectory during the first six months of postnatal life. Preliminary results show that girls tend to have higher Retzius periodicities linked to lower birth weight, while males seem to exhibit the opposite condition. Ongoing research will explore links between the biorhythm, gestation length, birth conditions, and diet during the early childhood years.

**Keywords:** enamel, retzius periodicity, daily cross striations, growth factors, histology

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# Stress, dental development, and life history in mandrills (*Mandrillus sphinx*)

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Dental development is frequently used to reconstruct life history in primates for which little other information exists. In addition to the regular growth increments visible in histological tooth sections, a set of accentuated lines are thought to form at the time of stressful incidents in the lives of individual animals. However, our understanding of when, how and why such accentuated lines form and how they relate to particular stressful events is limited. We tested the hypothesis that accentuated lines in the enamel and dentine are associated with stressful events in the lives of two male and two female semi-free-ranging mandrills (*Mandrillus sphinx*, Cercopithecidae) from the Centre International de Recherches Médicales, Franceville, Gabon. We used dates of birth, death and the known effect of annual veterinary captures on accentuated line formation to calibrate dental histology to calendar time and individual age. We then matched the accentuated lines in their teeth with the dates of known events in the mandrills' lives. Our results suggest that accentuated lines correspond to potentially stressful events, including the resumption of reproductive cycling in the mother and the birth of siblings, and menstrual cycles and parturition in females. Furthermore, our findings suggest that the number of accentuated lines recorded in teeth varies between individuals in a population, reflecting differences that may influence reproductive success.

**Keywords:** Accentuated lines, dental histology, physiological stress, life history events, Cercopithecidae

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# A study on early development of permanent incisors and canines

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Little is documented of the timing of early crown stages of permanent incisors and canines. The aim of this preliminary study was to describe the relative timing of the early forming permanent dentition including when the alveolar crypt is first observed. The sample consisted of individuals prior to full eruption of the first permanent molar (1554 dental radiographs of children aged 2-7 years of age and 620 modern skeletal remains from the British Isles). This included the documented age sample from Spitalfields, London. The method was describing the appearance of the alveolar crypt of permanent incisors, canines and first molars relative to tooth stages of developing teeth. Statistical analysis of data from radiographs included age of transition of some crown stages of anterior teeth using probit regression. The earliest observed crypt of the permanent central incisor was late crown stage of the deciduous central incisor in both jaws. The earliest observed crypt of the permanent canine was early root stage of the deciduous canine. The mean age of transition of permanent maxillary central incisor crown three-quarters and canine half-crown were both around 2.6 years. These findings allow a better estimate of early formation times of permanent anterior tooth formation.

**Keywords:** Archaeology, radiograph, crypt, crown, development

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# Dental evidence for middle childhood

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Comparisons of the growth and maturation of extinct hominins with modern humans have focused on differences over the entire period of development. This level of analysis may be too broad to provide meaningful insights. Further, data amassed over recent decades indicates that human growth is not circadian but rather occurs episodically with variations in the duration and frequency of growth episodes, suggesting that caution must be exercised in using modern dental standards to reconstruct growth and development in extinct hominins. There is, however, one part of the developmental period that distinguishes humans from chimpanzees and may have implications for our understanding of the emergence of human cognition. Between the eruption of the initial permanent teeth, the incisors and first molar, there is a time from seven to ten or eleven years of age, when no teeth erupt. This time, termed the 'Quiescent Period' by Eveleth and Tanner (1976) is followed by the eruption of the two premolars, canine and second molar. The Quiescent Period in dental maturation appears to be coincident with the developmental age known as Middle Childhood, a time when a youngster's ability to utilize the cultural norms of its society emerges. It is interesting that the brain almost achieves its adult size just prior to the onset of Middle Childhood and puberty immediately follows it. The Quiescent Period is documented from the assessment of both eruption and dental calcification derived from the X-rays and CB CT scans of children. Examination of the dentition of immature fossil hominin specimens, australopithecines and members of *Homo*, reveals the presence of the Quiescent period, whereas dental development in chimpanzees lacks this time. It is suggested that Middle Childhood evolved early in hominin evolution, perhaps prompted by the need to internalize knowledge of foraging patterns in seasonally variable mosaic environments.

**Keywords:** Middle Childhood, human dental development, hominin dental evolution, Quiescent Period, human evolution

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# Comparison of histological and radiographic assessments of molar development in Virunga mountain gorillas from Rwanda

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Dental development chronologies established from wild populations of our closest living relatives, the great apes, represent valuable tools for their veterinary monitoring, and also provide an important comparative reference in efforts to reconstruct life history evolution in the human fossil record. However, opportunities to examine known-aged individuals from wild populations are rare and some taxa are poorly known. We report on a histological examination of permanent mandibular molar development in Virunga mountain gorillas (*Gorilla beringei beringei*) from Volcanoes National Park, Rwanda (N=6, 2.8-est. 8 years), and compare these findings to a recent radiographic study of the same population (N=43, 0.0-14.9 years; Kralick et al. 2017). We used histological methods to determine cusp-specific initiation and formation times, daily secretion and extension rates, and other crown and root formation parameters. Initiation of M1 calcification occurred at a mean 0.21 years (range: 0.12-0.27, mb cusp) before birth, which is earlier than estimated using radiographic criteria. Completion of the M1 mesiobuccal enamel cervix occurred at a mean age of 2.14 years (range 1.79-2.32), compared to a midpoint age at attainment of 2.53 years assessed radiographically. In two individuals, M2 initiation occurred 0.16 and 0.33 years before M1 crown completion, which confirms the radiographic assessment of minimal overlap between M1 and M2 crown formation. Despite challenges due to the cross-sectional nature of our dataset, these and other findings indicate that histological studies are important for refining established chronologies of dental development in wild mountain gorillas, and for understanding the mechanisms that may contribute to differences in dental development timing compared to other great apes.

**Keywords:** mountain gorillas, dental development, microanatomy, radiographs

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# LEH defects and accentuated striae: do they co-occur in great ape canines?

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Developmental defects are used to reconstruct the stress experiences of primates. Linear enamel hypoplasia (LEH) occurs as pronounced grooves on the outer tooth surface and is associated with periods of malnutrition, injury, and illness in modern humans. Accentuated striae (AS) are microscopic features visible in the internal enamel structure. AS are associated with birth in the form of the neonatal line, and have also been found to correspond with post-natal immunizations, parturition, disease, trauma, and other stressors. AS and LEH defects are understood to reflect the same biological process, a temporary disruption to enamel secretion, but only a few cases of co-occurrence have been reported in the literature. Additionally, it is not yet clear whether AS is a more sensitive indicator of minor stress events, recording disruptions to enamel section that are of a shorter duration or reduced severity compared to LEH. Here, 13 mandibular canines representing four great ape taxa (*Gorilla beringei beringei, Gorilla gorilla gorilla, Pan troglodytes,* and *Pongo sp*.) were visually assessed for LEH presence following the standard protocol. Associated thin sections were viewed using transmitted light microscopy to determine whether AS co-occur at the onset of each LEH defect (N=78). In all cases where LEH defects were observed, AS were found to co-occur. However, each thin section was found to have more AS than LEH defects. Histologic analyses provide detailed reconstructions of the response to stress episodes, and allow a deeper understanding of the microstructural formation of LEH. By incorporating available life history records, it is possible to assess the type and duration of stress events that correspond with LEH defects and AS vs. AS alone.

**Keywords:** developmental defects, stress, great apes

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# How was your mother? Inferring human fetal growth patterns and maternal health from the prenatal enamel microstructure

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The reconstruction of the biological association between the mother and the fetus is a challenging task in paleoanthropology. However, its knowledge can be crucial in understanding biological and biocultural adaption dynamics of past populations and could represent a key factor in differentiating the ontogenetic trajectories among hominins. The timing and modality of the prenatal dental enamel formation can shed light on the maternal-fetal life course; indeed, some of the fetal growth parameters, the possible stresses suffered in utero - mirroring the mother's health status - and the length of the pregnancy can be estimated from the dental enamel microstructures in the primary dentition. Conversely, most of the available comparative data on the prenatal enamel derive from modern reference collections and are almost exclusively analyzed together with the postnatal portion of the crowns. Here we report data on crown formation time, daily secretion rate, enamel extension rate, and prevalence of Accentuated Lines in the prenatal enamel of 30 individuals from the Italian Imperial Roman necropolises of Velia (I-II century CE, Salerno) and Isola Sacra (I-IV century CE, Rome). Moreover, the topographic variation of the daily secretion rate across the prenatal enamel has been rendered. A subsample from Velia has been measured by high-resolution, phase-contrast synchrotron X-ray microtomography at the SYRMEP beamline of the Elettra - Sincrotrone Trieste laboratory (Italy) showing the suitability of this facility in the virtual histomorphometrical analysis of the prenatal enamel. Results illustrate a significant difference between the modern reference series and the archaeo-logical populations analyzed, highlighting the needs to create new standards of prenatal enamel formation patterns for pre-industrial populations. Moreover, the parameters derived from the archaeological series have been applied to the Ostuni 1b Upper Paleolithic fetus, re-assessing its gestational age-at-death and evaluating the maternal-fetal health history through a non destructive approach.

**Keywords:** prenatal enamel, prenatal enamel growth, fetal life course, maternal, fetal relationship, virtual histology

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# Undocumented anatomical trait common to Neandertal and extant Human on the upper deciduous incisor crown of individuals in perinatal period: anatomical description and micro-CT study

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Non-metric variations of perinates are a highly topical issue related to the increasing scientific interest in non-adult biological diversity. In particular, non-metric dental traits in deciduous teeth are rarely reported despite their potential value in biological affinities discussions. Here we provide an overview of existing literature, unpublished observations as well as one particular case study on a particular trait common to the Le Moustier 2 neonate Neandertal and extant Human perinate. An unusual anatomical feature (a small foramina) was noted on the lingual surface of three of the four deciduous upper incisor crowns of the Le Moustier Neandertal perinate. Two of these teeth also showed a clearly marked bulbous projection. Corresponding anatomical features also exist on the internal surface of the tooth. This feature was also observed in the collection of modern individuals of the Classic Kerma necropolis 8B51 of the island of Saï (North-Sudan), a site solely consisting of neonates and very young children. The foramina were macroscopically identified on two upper incisor crowns of two specimens from this collection. A detailed anatomical description is provided based on macroscopic and micro-CT approaches for some of them and interpreted in relation to its dental developmental stage. Its presence on both Neandertal and extant perinates leads to a questioning of its origin as well as its significance in terms of odontological dynamics or anomalies. By reporting on this previously undocumented trait, we stress the importance of investigating non-metric traits in deciduous teeth of current and past populations, and their potential for inferring dental developmental patterns in modern and fossil samples.

**Keywords:** non-metric variation, newborn, Neandertal, mineralization, tooth

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# Variation in human prenatal enamel formation rates of permanent first molars

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Enamel formation in permanent first molars usually initiates before birth. The timing of initiation, and prenatal enamel formation rates in this tooth type, has recently been shown to be more variable than previously thought. In this preliminary study we examined prenatal daily enamel secretion rates in the mesio-buccal cusp of n=20 maxillary first molars from four archaeological populations in England. Histological thin sections were prepared using standard methods. Daily secretion rate was measured between the dentin horn and the neonatal line in cuspal enamel. Results show that mean daily secretion rates increase from the dentin horn towards the neonatal line in all populations. Mean prenatal secretion rates were slightly lower in two populations, but the prenatal enamel area remained constant between all populations. The slower rate of enamel formation was linked to an earlier age of prenatal initiation, producing a similar amount of enamel before birth compared to the populations with faster secretion rates. Ongoing PhD research will further explore these possible population differences in prenatal enamel formation.

**Keywords:** Prenatal, Enamel, Secretion, Histology, Medieval

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# Social differences and the onset of puberty: study from teeth mineralization in two populations of the Great Moravia (9-11th centuries, Czech Republic)

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We report results of pubertal age estimation based on teeth mineralization of two archaeological populations originating from the Great Moravia (9th-11th centuries, Czech Republic) with different associated socio-economical statuses. Teeth mineralization stages have been shown to correlate with the apparition of other developmental events that take place during puberty; the development of canines and premolars are notably known to be reliable indicators of the onset of menarche. Diet, pathology, living conditions influence the onset of menarche, as well as teeth mineralization to a certain extent. A total of 108 juvenile skeletons were studied, ranging from 7 to 20 years of age. We used two methods based on teeth mineralization to assess pubertal development of each individual as well as a method based on cervical vertebrae maturation. Half of the sample comes from Mikulcice which is known to be a major political and economical centre of the Great Moravia (Early Middle Ages, 9th century, South Moravia, Czech Republic); the other half originates from Rajhrad (second half of the 9th century and 10th century, same location) where the necropolis is associated with the cultivation of hops. The hypothesis of different social statuses is given by the archaeological context. How the socio-economical status in uences pubertal development in those two populations is explored and discussed.

**Keywords:** teeth mineralization, Great Moravia, Central Europe, puberty, menarche, social differences

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# Tooth emergence as a significant event in life history

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How much can we learn about the past from the dental development of extinct species? We have now recovered the age of first molar eruption in early fossil hominins, for example, but does that take us close to population fundamentals or is it, along with size measures, a more distant "life-history related" marker? The question needs to be addressed from both theoretical and empirical sides.

Theory: "Life history" is often equated with life table events, such as gestation length, age of weaning, fertility, mortality, and life span. These *components of fitness* are crucial to calculating the demographic future of a population. Life history theory, however, has a different emphasis: an organism's life history *is the product of an evolved strategy of the allocation of time and energy to growth, maintenance, and reproduction*, where available options are limited by mortality risk and energetic budget.

Empirics: Vinicius and Mumby's ß (beta), a dimensionless measure of postnatal growth rate, can be matched to age of emergence of the first permanent molar for N=19 primate species. First molar emergence is a good predictor of ß, at $R2=0.72$, at $R2=0.45$ ($p< 0.05$) if corrected for phylogenetic relatedness.

This result support the interpretation that tooth emergence is tightly integrated into somatic growth. Slowed growth is a principle adaptation of higher primates, a sign of a shifted energy balance that, in humans especially, likely supports investment in cognition. Age of first molar emergence is an index of growth rate in species; previous work shows that emergence of the first permanent molar is associated with the transition to independent feeding in primates and other mammals. In sum, teeth are what mammals use to make their living; their development is a principle tool to recover elements of life history from the fossil record.

**Keywords:** life history, primates, human evolution, dental development, tooth emergence

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# Experimental manipulations of biological rhythms in Mammalian teeth

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Enamel- and dentine-forming cells produce incremental growth lines through rhythmic secretions. Experimental studies of mammals have demonstrated that these lines reflect circadian biological rhythms, which are likely under neurological control. For example, a Japanese team reported that experimental lesioning of the suprachiasmatic nucleus (SCN), a key regulatory region in the brain, halted the formation of daily growth lines in rats. However, given that finer sub-daily lines persisted after SCN damage, we decided to reexamine the role of the SCN in growth line formation. The Animal Research Ethics Board at the University of Saskatchewan approved all experiments. Thirteen 7-week old Wistar rats were individually housed and acclimated to a normal 12:12 hour light/dark cycle for two weeks with food and water ad libitum. Rats were subdivided into three treatment groups: non-surgical control (N=1), sham SCN surgery (N=6), and SCN electrolytic lesion surgery (N=6). Twelve rats were injected subcutaneously with lead nitrilotriacetic acid (Pb-NTA) to create known time-markers in developing incisors. Five days after the first injection, six rats underwent a SCN lesion surgery according to the protocols of the original Japanese study. On the day of stereotaxic surgery, all rats received a second injection of Pb-NTA and were transferred into constant light conditions. This was followed by a third and final injection of Pb-NTA seven days later. Four days hence, all rats were sacrificed, and the brain and jaws were dissected out and fixed. Brains were sectioned to verify SCN lesions. Incisors were decalcified, sectioned, and stained to identify lead labels. We found that daily and sub-daily growth lines persisted in teeth even after the SCN was lesioned. Elucidating other regulatory mechanisms is critical to explain the relationship between hard tissue biological rhythms, dental development, and mammalian life histories.

**Keywords:** incremental features, circadian rhythms, suprachiasmatic nucleus, biological clocks, tooth development

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# Mineralization front in enamel of pig molar studied using microCT and modeling

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The domestic pig (*Sus scrofa domesticus*) is a plant-dominated omnivore with large, low-crowned molars. The relatively fast tooth development together with large size, thick enamel and complex crown morphology makes pig molars a suitable model for the biomineralisation studies. Here we report and examine the complex patterns of the advancing mineralization front of pig molars. MicroCT absorption models of developing pig molars were obtained. Horizontal sections of cusps demonstrate complex patterns of mineralization in which concave and convex enamel-dentine junctions (EDJ) produce different mineralization patterns. Furthermore, the mineralization front changes shape going from the EDJ to the enamel surface. The shape of the mineralization front does not directly reflect the EDJ shape or the enamel surface shape. Furthermore, enamel thickness varies in pig molars and the patterns of mineralization are highly variable among the cusp. We implemented a simulation in which the growth of the mineralization front is limited by the diffusion of constituent materials, producing fractal-like patterning. We tested different model assumptions, such as in which either dentine or the ameloblast layer was considered as the material source, and also considered different boundary conditions at the perimeters. The outputs of the different simulations were then compared with the empirical patterns of enamel mineralization in pig molars. The results are suggestive that modeling approaches are useful in inferring the process of biomineralization.

**Keywords:** enamel, mineralisation, modeling, pig, microCT

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# 4. Dental function and biomechanics

# Bone microstructure and gene expression in the mouse mandibular head after botulinum toxin-induced masseter muscle paralysis

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During dental occlusion, masticatory muscle contraction provides biomechanical stimuli, which are relevant for masticatory efficiency and temporomandibular joint homeostasis. Masseter muscle paralysis induced by botulinum toxin produces bone loss in the mandibular head of growing mice and adult rats. However, the cellular and molecular mechanisms behind this process are not completely understood. We used an in vivo mouse model to assess the effects of this intervention at microstructure and molecular levels on the mandibular head. An intramuscular injection of botulinum toxin type A induced masseter muscle paralysis in the right side (experimental) of adult BALB/c mice (n=11; 7 weeks). As a control, the left masseter was injected with saline solution. After 2 days (n=2), 7 days (n=3) and 14 days (n=6) of intervention animals were euthanized. Masseter muscles and mandibular heads of both sides were collected. Immunofluorescence and bone histomorphometric analyses (Bone Tissue Fraction [B.Ar/T.Ar] and Trabecular Thickness [Tb.Th]) were performed for microstructure assessment of the masseter muscle and mandibular head, respectively, at 14 days following intervention. In addition mRNA relative expression was quantified in both tissues at 2 and 7 days. The bone resorption promoter (*Rankl*) was 4.7-fold higher at day 2 in the experimental side compared with the control. At day 7 an increase in muscle atrophy (*Atrogin-1* and *MuRF*) and muscle regeneration (*Myogenin*) molecules was found. After 14 days, masseter muscle mass and single masseter ber diameters as well as B.Ar/T.Ar and Tb.Th in the mandibular head were significantly reduced in the experimental side. This mouse model will allow for the study of the mechanisms that induce rapid bone loss in the mandibular head as acute response/adaptation to altered muscle function in the masticatory apparatus, a topic of wide interest in developmental biology, anthropology and dentistry.

**Keywords:** Mandibular head, masseter muscle, botulinum toxin type A, muscle paralysis, bone lo

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# Exploratory study of microwear signatures in human deciduous molars from the Tooth Fairy collection: methodological considerations

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Microwear texture analysis using a confocal microscope and scale-sensitive fractal analysis has made major contributions to dietary reconstruction in the last 15 years. However, very little work has been done with deciduous human teeth. Furthermore, the interpretation of microwear signatures remains difficult as many aspects of microwear formation are still poorly understood and the impact of differences in deciduous enamel composition and masticatory biomechanics is still unknown. In order to discuss methodological considerations, and improve interpretations of microwear texture analysis from deciduous archaeological samples, an exploratory study was conducted into the microwear signatures in the Tooth Fairy collection, a reference sample of deciduous teeth with documented records for individuals. All tests were conducted on phase II facets of deciduous molars. 6 microwear texture variables were calculated using Toothfrax and Sfrax. Intra-facet and inter-facet variabilities were measured for 15 individuals to discuss acquisition methodology. Variability between facets of Udm1, Ldm1 and Udm2 was measured in 15 teeth (5 of each type) to discuss the potential impact of the position of the molar in the dental row. The impact of certain biological factors affecting early life and potentially influencing amelogenesis was also estimated for 6 individuals in order to discuss non-dietary sources of variability in deciduous microwear signatures. Preliminary results showed unexpected high variability in microwear signatures between different measurements across the same facet. Control tests revealed it was difficult to visually detect the edges of the wear facet and any topographical anomalies impacted the signature significantly. Better selection of samples improved the PCA's ability to distinguish between individuals. Anisotropy (epLsar) and complexity (Asfc) variables were found to better group individuals from the same family than the other texture variables: large-scale heterogeneity (Hasfc9), fine-scale heterogeneity (Hasfc81), coarse texture fill volume (CTfv) and fine texture fill volume (FTfv).

**Keywords:** microwear texture analysis, wear facets, deciduous molars, microwear signature

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# Exploring the dietary plasticity of *Eucladoceros ctenoides*: what does its occurrence in the fossil record mean?

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Cervidae are often used as paleoenvironmental proxies during the early Pleistocene as they are particularly abundant and diversified during this period of *Homo* dispersal in Europe. This family has been used for long in the framework of environmental reconstructions, and the presence of deer in a fossil locality is traditionally interpreted as witnessing a significant tree cover in the habitat. Among cervids, the large deer *Eucladoceros ctenoides* is present through the whole Europe during the Villafranchian (3.5-1.1/1.0My) and presents a body mass similar to that of extant European *Cervus elaphus*. We explore for the first time the dietary plasticity of this emblematic extinct deer, through the analysis of dental microwear textures of 145 *Eucladoceros ctenoides* from seven early Pleistocene European localities. Considering the large body mass of *Eucladoceros* we expected this taxon to present a significant dietary plasticity. Being the extant European deer with the higher dietary plasticity, we compared our results with two modern red deer populations. Red deer from the Polish primeval forest of Bialowieza are engaged in browsing while their Spanish counterparts from Lugar Nuevo are much more engaged in grazing. The dental microwear texture results mirror the feeding preferences of the fossil deer: either dicot foliages, seeds or tough and abrasive monocots. The wide range of variation of its dental microwear signal illustrates the diversity of the food categories this taxon is able to consume and therefore its important dietary plasticity. These results are not surprising when compared with the plasticity in dietary habits of modern Red deer. However, there are at odds with traditional paleoenvironmental interpretations. In our study, we show that the occurrence of *Eucladoceros ctenoides* in itself as a proxy for paleoenvironmental reconstructions is awed. The dental microwear textures of this deer, rather than its occurrence, constitutes an adequate paleo-habitat proxy.

**Keywords:** Cervidae, feeding ecology, paleo, environmental reconstructions, Dental Microwear Texture Analysis, early Pleistocene

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# Ecological differentiation in *Homo naledi*

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*Homo naledi* is characterized by a mosaic of archaic, *Australopithecus* like, and derived, *Homo* like, traits, suggesting it occupied a unique ecological niche within *Homo*. Dietary reconstructions inform niche reconstructions and are particularly successful when using dental material. Tooth shape (via dental topography) and size were quantified for four taxa of South African hominins (*Australopithecus africanus, Paranthropus robustus*, Early Stone Age (ESA) *Homo*, and *H. naledi*), on relatively unworn M2's to investigate possible ecological differentiation in *H. naledi* relative to geologically similar taxa. *Homo naledi* has smaller, more tall-crowned (hypsodont), and wear resistant teeth than *Australopithecus* and *Paranthropus*, and appears to have more hypsodont, wear resistant teeth than ESA *Homo*. Although shape metrics are sensitive to tooth wear, the same patterns of results were found in moderately worn and lightly worn teeth. This indicates the same ecological factors that differentiate *H. naledi* from *Australopithecus*/*Paranthropus* also differentiate it from ESA *Homo*, and in the same direction. It is not possible to know whether this is a dietary and/or environmental adaptation, as more hypsodont and wear resistant teeth represent adaptions towards mechanically resistant diets and arid environments. Compared to the great apes, hominins had sharper teeth, indicating all hominins occupied an ecological niche which required higher shear forces during mastication. Despite some anatomical similarities, *H. naledi* occupied a dietary niche distinct from that of the other South African hominins.

**Keywords:** *Homo naledi*, *Paranthropus robustus*, *Australopithecus africanus*, Early Stone Age *Homo*, dental topography

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# A palimpsest of diseases: the relation of temporomandibular joint osteoarthritis with ante mortem tooth loss in a medieval sample from Coimbra, Portugal

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The aim of this presentation is to analyze the relationship between osteoarthritis of the temporomandibular joint (TMJO) and ante mortem tooth loss (AMTL) in 44 adult dentitions, from São João de Almedina archaeological medieval urban population (Coimbra, Portugal). The sample is comprised by 24 males, 14 females and 6 individuals of unknown sex - divided into three age classes - with at least one jaw present. For the registration of AMTL we followed the recommendations of Hillson (2001). All alveoli were seen under a strong direct light with a magnifying glass and classified under ante or post mortem tooth loss or in remodeling process. For the TMJO we relied on the Rando and Waldron (2012) recommendations to record the cases of eburnation and also the presence of osteophytes, porosity and alteration of joint contour both in the mandibular condyle and in the articular eminence. TMJO was diagnosed when eburnation or at least two of the last three were present. Approximately 73% (n = 32) individuals and 18% (n = 218) alveoli were affected by AMTL. This condition affected mostly middle aged adult men and the alveoli on the lower jaw. The TMJO was present in 59.1% (n = 26) individuals and 34.8% (n = 39) of the observable condyles. Both conditions are more visible on middle aged masculine individuals and the lower jaw (mandibular condyle). These results suggest that the oral pathologies at the origin of the AMTL are related with the later appearance of TMJO and may have an impact in the quality of the chewing process. This study highlights the need to investigate the interrelation between distinct oral conditions which is particularly clear when we look at the biomechanical aspects of the masticatory process and to the degree of completeness of the dentition.

**Keywords:** São João de Almedina, dental pathology, quality of life, archeological samples, chewing

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# Molar macrowear variability within the Neandertals from El Sidron (Spain)

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In this study we analyze the well preserved occlusal macrowear pattern of the Neandertal individuals from El Sidron site in Northern Spain by applying the Occlusal Fingerprint Analysis (OFA) method to reconstruct their wear facet distribution and occlusal pathways. Wear facets on the occlusal surface of molar crowns were quantified from digitized casts, and functional parameters such as the area, orientation, and inclination were measured. 3-D occlusal dental compasses of single molars indicate major movements during mastication. This allows to explore the individual variation among this group. The overall power stroke pattern of the group is characterized by a dominance of buccal and lingual Phase I, whereas Phase II is less developed. All seven adult and four sub-adult individuals reflect a common occlusal motion pattern. No changes during ontogeny or differences between male and female indicate similar food choice within this group. The macrowear pattern is similar to that of other Neandertals characterized as mixed diet consumers who occupied deciduous woodland habitats. Furthermore, we found that two adults show slight differences in the wear facet pattern. Sidron Adult 2 left m2 possesses a higher percentage of Phase II and buccal Phase I facet area. This describes a moderate functional shift in the occlusion which may have occurred in relation to the oral pathology already published for this individual. Additionally, Sidron Adult 6 shows the common wear distribution, but differs in the inclination and orientation of the facets' vectors due to the advanced wear stage of the molars, resulting in a strong overlap of the occlusal surfaces of the antagonists in maximum intercuspation.

**Keywords:** Occlusal Fingerprint Analysis, Macrowear, Dietary reconstruction, Intra, group variability, *Homo neanderthalensis*

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# Functional tooth wear inclination in great ape molars

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Primate dietary diversity is reflected in their dental morphology, with differences in size and shape of teeth. In particular, the tooth wear angle can provide insight into a species' ability to breakdown certain foods. To examine dietary and masticatory information, digitized polygon models of dental casts provide a basis for quantitative analysis of wear associated with tooth attrition. In this study we analyze and compare the wear patterns of *Pongo pygmaeus* (N = 10), *Gorilla gorilla gorilla* (N = 10) and *Pan troglodytes schweinfurthii* (N = 10) lower second molars, focusing on the degree of inclination of specific wear facets. The variation in wear angles appears to be indicative of jaw movements and the specific stresses imposed on food during mastication, reflecting thus the ecology of these species. Orangutans exhibit atter wear angles, more typical of a diet consisting of hard and brittle foods, while gorillas show a wear pattern with a high degree of inclination, ref;ecting thus, their more leafy diet. Chimpanzees, on the other hand, show intermediate inclinations, a pattern that could be related to their highly variable diet. This method is demonstrated to be a powerful tool for better understanding the relationship between food, mastication and tooth wear processes in living primates, and can be potentially used to reconstruct the diet of fossil species.

**Keywords:** tooth macrowear, ecology, diet, mastication, living primates

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# 3D quantification of the occlusal enamel curvature: a decisive feature in dental function analysis and diet in Primates

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Occlusal cusp pattern and shape are classically used as the primary descriptors of dental morphology in mammalian taxonomy and phylogeny. In functional terms, dental morphology can be treated as a suite of tools used to process food items through various mechanical actions, potentially representing adaptations to mechanically challenging foods. Hence, the different cusp/crests geometries serve to perform different kinds of mechanical actions and the occlusal pattern can be viewed as a combination of mortars, pestles, blades, and wedges, which are used to process food items through slicing, crushing, grinding, shearing and/or puncturing actions. The 3D dental topography is a powerful tool to quantify dental occlusal geometries. We propose a method to quantify the normalized curvature variation of the enamel occlusal surface. The enamel curvature, its variation and its magnitude, is a key parameter in retrieving dental functions since dental feature curvature has direct outcome on dental tool expression and efficiency and is suggested to be decisive in interpreting dietary adaptations trough primate evolutionary history. Thus, low curvature better characterizes blunt features (e.g. cusps) involved in crushing while high curvature expression rather depicts sharp features (e.g. blades) involved in slicing and/or puncturing. We aim to quantitatively assess the occlusal enamel curvature variations through 3D topographical methods in order to appraise occlusal patterns in terms of blunt, at, or sharp reliefs. We performed a quantitative comparative analysis of enamel occlusal surface in 80 primate second upper molars, which are represented by polygonal meshes. For each molar, we computed a normalized version of the mean curvature for the whole tooth and its occlusal portion and compare curvature area expression among primate taxa. The normalized curvature allows differentiating quantitatively dental patterns within Primates and offers the opportunity to interpret dental patterns in terms of functions potentially representing adaptations to mechanically challenging foods.

**Keywords:** 3D Dental topography, curvature, enamel surface, dental tools

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# Dental microwear: teasing out the complexities

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For many years anthropologists have considered dental micro-wear patterns as providing the blueprint for determining the dynamics of masticatory function. Microwear analyses of human teeth have confirmed the presence of two predominant orientations. There are transverse (i.e., bucco-lingual) scratches resulting from the final phase of the masticatory power-stroke when the mandible approaches intercuspal position (IP) and oblique scratches that have been interpreted as resulting from mandibular teeth moving past the IP in an oblique direction. This 'oblique pattern' gave rise to the concept of the 'lingual phase of the masticatory stroke' and has been considered as a 'contact glide' during opening. However, microwear produced by tooth grinding without the presence of food also displays a similar pattern and is often over-looked by anthropologists as a contributor to dental wear. In addition, microwear resulting from grinding also challenges the concept of the lingual masticatory phase. We have assessed and quantified the frequencies of matching facets in 400 randomly selected patients and 59 pre-contemporary Australian Aboriginals. Our results indicate that tooth grinding is a common behaviour that contributes to dental micro-wear patterns in humans. Early explanations relating to function, based on micro-wear interpretations need to be viewed with caution. Facets produced by grinding are distinct and different to wear 'areas' produced by dietary abrasion. However, the micro-wear detail resulting from each mechanism is superimposed making interpretation difficult. Observed wear merely reflects the predominant mechanism acting on an individual at that time. In addition, these patterns also seem to support the opinion that the mandibular movement during grinding occurs in the opposite direction to the masticatory stroke. Further research is required to differentiate wear resulting from tooth-to-tooth contact without the presence of food and that produced by the abrasiveness of the diet.

**Keywords:** microwear, wear, tooth, grinding, mastication, facets

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# Quantification of the involvement of enamel thickness variations in production and modification of occlusal dental traits in Primates

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Occlusal cusp pattern and shape are classically used as the primary descriptors of dental morphology in mammalian taxonomy and phylogeny. In functional terms, dental morphology can be treated as a suite of tools used to process food items through various mechanical actions, potentially representing adaptations to mechanically challenging foods. A tooth must also resist wear and fracture, which can be accomplished through thickness variations of the enamel cap. The enamel-dentine junction (EDJ) is interpreted as a precursor for the morphology of the occlusal enamel surface (OES) through growth of the enamel cap, which has also been reported to add original features such as wrinkles viewed as gripping dental tools. Here we aim to quantitatively assess the relative implication of enamel thickness variations in producing and/or modifying dental features/tools in primates. We performed a quantitative comparative analysis of EDJ and OES in primate second upper molars, which are represented by polygonal meshes and investigated using three-dimensional topographic analysis. Quantitative criteria (elevation, inclination, orientation, curvature, complexity) show a significant correlation ($p < 0.05$) between OES and EDJ for all studied primate taxa except for curvature in modern humans. Our analysis does not support the presence of occlusal traits without dentine relief nuclei, including in taxa displaying wrinkles and crenations. Our results suggest a primary emergence of dental tools on EDJ and a secondary transposition of these tools with minor modifications of functionalities by the enamel cap. For all topographical parameters except complexity, the recorded correlations however decrease along with enamel thickening in our sample. Enamel thickness variations may notably modify the curvature present at OES in relation to EDJ, potentially modifying dental functionalities such as blunt versus sharp dental tools. In terms of natural selection, there might be a balance between increasing tooth resistance via enamel thickening and maintaining e cient dental tools.

**Keywords:** 3D Dental topography, enamel, dentine junction, enamel cap, dental tool, selection

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# Temporomandibular joint pathology in Eastern Atlantic harbour seals (*Phoca vitulina vitulina*) from the German Wadden Sea

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Skulls of 1872 Eastern Atlantic harbour seals from the German Wadden Sea (collected between 1961 and 1994) were examined for the frequency and severity of temporomandibular joint osteoarthritis (TMJ-OA). Furthermore, possible associations of TMJ-OA with other dental or periodontal pathologies were analysed. Age-at-death determination via cement-layer analysis of the seals (Abt 2002), enabled a reconstruction of birth years for the studied individuals. 913 skulls (48.8%) were from male, 959 (52.2%) from female seals, with age-at-death ranging from 2 weeks to 25 years for both sexes. Lesions consistent with TMJ-OA were found in 963 specimens (51.4%), the condition mostly (95.0% of affected individuals) occurring in a bilateral fashion. Males were affected more frequently by TMJ-OA than females (p=0.001), while lesion severity tended to be higher in females (p=0.028). Severity of TMJ-OA was strongly correlated with age (rs=0.689, p< 0.001). TMJ-OA severity was also weakly correlated (partial correlations, p< 0.05) with the number of tooth fractures (rs=0.053) and of intravitally lost teeth (rs=0.111), when controlling for age-at-death as a confounder. A minor effect of birth year on the severity of TMJ-OA (rs=-0.096) was shown. This could indicate a minor effect of exposure to organochlorine contaminants (higher during the 1960s and 1970s than during later periods) on the prevalence and severity of TMJ-OA in the harbour seals. The causes underlying the high prevalence of TMJ-OA in the studied assemblage remain unknown. Most specimens (75.0 %) were found dead during the first phocine-distemper-virus epizootic in 1988-89. Therefore, it is assumed that little or no overrepresentation of pathological conditions is present in this death sample. It is suggested that especially marked and severe TMJ-OA decreased the survival probability of the affected individuals with effects on the demographic structure of the population.

**Keywords:** temporomandibular joint, osteoarthritis, harbour seal, North Sea, wildlife diseases

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# Adaptive phase II elongation from fossil to modern apes

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Fossil apes are known mainly from eastern Africa and southern Europe since the Miocene. As a common evolutionary feature of functional dental adaptation usually they develop a pattern of 13 complementary wear facets in their upper and lower molars during individual life history. This pattern reflects power stroke movements of mastication. Wear facets 1-4 are attributed to occlusal buccal Phase I, wear facets 5-8 represent lingual Phase I and wear facets 9-13 develop in Phase II. Accordingly, the acquisition of the percentage distribution of wear facet areas on a molars' occlusal surface enables computation of power stroke phase ratios. We have investigated wear facet patterns on digital models of molars from various groups of fossil and modern apes in order to reconstruct proportions of occlusal movements. Results show that Phase II prevalence has evolutionary developed as the common mode of power stroke towards modern apes compared to fossil African proconsulids. Additionally, distinct differences in the distribution of upper and lower molar Phase I wear facets are recorded in all sample groups with the exception of proconsulids. This indicates that dominant lateral movements during occlusion occurring already at closing Phase I are responsible for the production of enlarged buccal Phase I versus lingual Phase I wear facets in upper molars. We found an opposite functional correspondence in lowers. This leads to the assumption that the development of an elongated lateral power stroke trajectory in both phases can be interpreted as evolutionary masticatory adaptation for an advanced biomechanical processing of relatively tough food. This enhanced tensile force functionality prevails independently from variations in wear facets inclination which permit more or less cutting capability.

**Keywords:** Dental adaptation, mastication, Power Stroke, wear facets, hominoids

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# Food, dust and tooth wear: a sheep perspective

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Both dust and phytoliths have been shown to contribute to reducing tooth volume during chewing. However, the extent to which they individually contribute to tooth wear is unknown. There is still debate as to whether dental microwear represents a dietary or an environmental signal, with far-reaching implications on evolutionary mechanisms that promote dental phenotypes, such as molar hypsodonty in ruminants, or enamel thickening in human ancestors. To explore this, we conducted a controlled-food testing on 40 sheep to assess tooth wear. Two groups of 10 ewes were fed on a multispecific assemblages of herbaceous monocots and a second 10-ewe couple were fed on a red clover-dominated fodder; the clover being less concentrated in silica phytoliths than grasses. Every day, a load of dust simulating natural conditions met in Western Africa was added to the fodder of one of the 10-ewe samples per diet category. Dental microwear textures were gathered on the disto-labial enamel band of the protoconid of the second lower molar. Regardless of the presence or the absence of dust, sheep with different diets yield significantly different dental microwear textures. The anisotropy and the textural fill volume of the dental microwear textures discriminate the dietary groups the most, with higher values for ewes fed on monocots. However, dust load tends to favor decreases in complexity and heterogeneity of complexity between clover-fed ewe samples. When surface parameters are compiled into a multivariate approach, browsers given a dust supplement differ from dust-free grazers even though browsing diets with a dust supplement contain more silica than dust-free grazing diets. Thus, dust appears a less significant determinant of dental microwear than foods, implying that diet plays a critical role in driving the natural selection of dental innovations.

**Keywords:** phytoliths, quartz, diet, enamel, experimentation

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# The effect of TMJ prosthesis on jaw's kinematical characteristics including muscle forces

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According to the released data, temporomandibular joint disease is a common maxillofacial issue in all over the world. In most cases temporomandibular joint replacement is prescribed by surgeons. Despite the evolution of TMJ prosthesis by optimizing its geometry and including the real circumstances, many other considerations should be taken into account in order to enhance its function and stability characteristics. In this research TMJ is replaced by TMJ prosthesis and the muscle forces were applied during opening-closing the jaw to study its effect on the range of its kinematical characteristics. In this research a CAD model of the intact and implanted mandibles are produced. Real surgery processes are simulated within ANSYS APDL environment. The movement of TMJ prosthesis under real muscle forces during opening and closing of jaw are modeled and the obtained results are compared with Koolstra et al.'s results. The obtained results show that the difference between mandible movement during opening and closing the jaw in intact mandible and the implanted prosthesis is not negligible which indicates the function of TMJ prosthesis should be improved. However, by optimizing the prosthesis at different parameters such as its geometrical properties and including real muscle orientations and positions in instantaneous muscle force equation, the determined information will show the closest outcomes to real situations. In this research the TMJ prosthesis replaced in its appropriate position and real conditions of muscle forces were considered during simulation. The results showed good agreement with experimental investigations. Therefore, the errors in the performance of a TMJ prosthesis comes from its shape and position. This error can also be due to the direction of muscle forces which in the previous studies have been ignored. Hence our model can provide a better insight on its performance and the optimized results will be tested to verify its performance.

**Keywords:** TMJ prosthesis, Finite element method, Optimization, Muscle mechanics, Jaw kine-matics

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# Asymmetry, balance and dental macrowear patterns of Yuendumu Aboriginals: a case study

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Real symmetry and perfect balance between opposite jaw halves and antagonistic teeth is not the reality in the masticatory system. Research results show that natural asymmetry in our body, skull and jaws is related to non-genetic environmental and individual ontogenetic factors. However, in modern human groups it seems we see an increase of variability in tooth spatial positions and asymmetry compared to non-human primates and most fossil hominins. The sample of Yuendumu Aboriginal people consists of complete maxillary and mandibular dental arch 3D models from 19 individuals (young and adult). The analysis was carried out on first molars from all quadrants. Only individuals with M1s with similar levels of wear were selected. Virtual models were oriented identifying a standard plane for the mandible and maxilla. Occlusal fingerprint analysis was used to obtain M1 macrowear patterns, and 2D cross-sectional geometric analysis of the jaws was carried out to investigate asymmetry in dental and palatal arches. A high variability in asymmetry was observed in both upper dental and palatal arches, correlating with differences in inclinations of upper M1 crowns. Significant values of correlation were observed in lower dental arch inclinations, likely expressing less plasticity in the mandible than in the maxilla. The wear facet positions on opposing teeth reflected the differences in inclination of the molars between left and right sides. Wear facets are produced by various factors (external and internal) that interact during ontogeny. Our results emphasize the important role played by asymmetry in the context of teeth erupting and finding their antagonistic positions in the masticatory system to produce dental macrowear patterns in modern humans. Asymmetry in our modern masticatory apparatus affects the relationship of opposing tooth contacts and hence observed wear patterns.

**Keywords:** Dental function, wear facets, asymmetry, alveolar arch, palatal arch

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# The criterion of temporomandibular joint wear in determining biological age

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The author considers the problem of determining the biological age on skull and materials of poor preservation. The main problem of the research is that in the paleopopulations the same criteria work in different ways. So the degree of dental wear depends on the quality and composition of food, the methods of its processing, the specific use of teeth, and pathological conditions. The sample was formed from the paleoanthropological materials of medieval Russian cities (7 necropolis, a total of 109 individuals). The age of individuals in the sample was determined on the basis of standard anthropological methods (complex markers fixed on the skull and postcranial skeleton). The aim is to develop an additional independent evaluation criterion on the basis of temporo-mandibular joint (TMJ) functional wear. The scoring scale was based on qualitative and quantitative characteristics:
- degree of bone relief of the cranial vault, in particular at the places of attachment of masticatory muscles;
- severity of buttresses of the lower jaw;
- degree of wear of occlusal surfaces of teeth;
- shape of the TMJ and mandibular condyles;
- absolute size of the TMJ - the total length of the joint site, the physiological length, the depth of the pit in the longitudinal and transverse as well as their ratio;
- pathological conditions and anomalies, local pathological loss of dental tissue, etc.
The tendency of the TMJ wear was revealed in connection with the age intervals of 10-15 years on the basis of the statistical data. Statistical analysis (one-way ANOVA, Kruskal-Wallis test) showed significant differences between sample medians. Correlation with the sex of individuals was not detected, which indicates the universality of the application. The set intervals reflect the trends of normal age characteristics and this is in a weak dependence on external factors.

**Keywords:** paleoanthropology, biological age, temporomandibular joint

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# Understanding the interproximal dental wear mechanism using 3D surface texture analysis

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Interproximal dental wear, which forms facets on the proximal surface of the tooth, is the result of differential movement of teeth during mastication. The wear facets are usually formed when a layer of enamel substance in the mesial and/or distal area of the crown are worn out. Therefore, interproximal dental wear is an important source of information regarding the masticatory apparatus and force transmission along the dental arch. In the current study, we aim to reveal the fundamental mechanism underlying the process of interproximal wear formation using 3D surface texture analysis. For each of the 15 modern human specimens collected from the dental clinic in Tel Aviv University, three regions of interest (center, border, outside) were selected as measuring spots for quantitative 3D surface texture analysis. Each region was measured in three spots using a high-resolution confocal disc-scanning measuring system (100x long distance lens, µsurf explorer, NanoFocus AG, Germany). Standardized ISO parameters (ISO 25178, ISO 12871) were applied on the surface measurements using Mountains Map Premium software version 7.3.7. (DigitalSurf, France). The results indicated different surface texture characteristics for each region of interest indicating lower roughness values on the center and higher roughness values on the outside areas. Based on the results, we suggest a new tribological model explaining the mechanism underlying interproximal facet formation. Understanding the process of formation can be used to shed light on the masticatory system and force transmission in ancient populations in the presence of fragmented specimens or even isolated teeth.

**Keywords:** Dental attrition, interproximal wear, microsurface, Facet, bite force

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# The relationship between maxillary bone development and dental eruption in humans: a study using microscopy and geometric morphometric techniques

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Ontogenetic changes in cranial morphology are the result of the interaction between bone modelling and bone displacement. Bone modelling is the cellular process that creates and removes bone tissue, while displacement describes how the bones of the skull move to achieve and maintain proper alignment. However, it is still unknown how variable bone modelling patterns in the face are, and to what extent they are linked to their nearest developing structures (teeth, sinuses, soft tissues). We assumed that the activities behind bone modelling (i.e., the intensity of production or removal of bone) strictly follow the development of those structures. In this study, we quantified the activities throughout ontogeny in the maxillary bone using microscopy and geometric morphometric methods. We used an ontogenetic series of 48 skulls of calendar ages ranging from birth to 12 years. High-resolution replicas of the bone surface were created using Epoxy resin and then investigated with a digital stereo microscope. In addition, a subset of 40 skulls was CT-scanned and ontogenetic shape changes in the maxillae were analyzed using a semilandmark approach. We found that woven bone is mainly present from birth to about 2.5 years of age indicating a period of fast development. Variability between individuals of the same age was high. In the same period, bone resorption increasingly occurs in the anterior part of the maxilla. The end of this phase corresponds to the eruption of the deciduous dentition and functional occlusion, and is characterized by an increase of compact bone. The next stages showed less variability within individuals, and a more constant resorptive activity. In conclusion, our results suggest that growth and development of the maxillary bone, at least in the first stages of ontogeny, is linked to the development of the deciduous teeth.

**Keywords:** Bone modelling, Dental eruption, Geometric morphometrics, Maxilla, Ontogeny

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# Seasonality and population specific tooth wear in forest-dwelling Western Chimpanzees (*Pan troglodytes verus*)

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Diet is directly linked to the environment, and has played a key role in human evolution. Previous dietary studies on primates often focused on interspecific variation in microscopic tooth wear, using dietary data from various published sources. Here we investigated whether dietary seasonality and habitat variation can be identified in tooth wear signatures within and between two chimpanzee populations. In detail we compiled feeding ecological data of 17 *Pan troglodytes verus* of the Taï National Park (Côte d'Ivoire), and interpreted them in relation to 3D surface texture (ST) data obtained from occlusal molar surfaces of the same individuals. Additionally, ST data were taken from molars in another population of the same subspecies (n=22), located in the northern part of the former Central Province of Liberia, where the annual precipitation is less than in the Taï National Park, but no dietary data exist. Results showed that molars of Taï chimpanzees which had died during the dry season showed lower peaks and valleys compared to individuals collected in the wet season. Moreover, Taï chimpanzee molars had distinct ST patterns when compared to those from Liberian chimpanzees. Since the dietary composition of the Taï chimpanzees was similar in both seasons, we suggest that the ST pattern of the dry season reflects higher amounts of dust particles on foods, which are carried into the forest by the Harmattan trade wind and may increase abrasive wear features. Furthermore, we relate the differences in the ST signals between the two populations to differences in annual precipitation rates. Our study shows how ST analysis on molars can be used to reveal variations in environmental variables such as seasonality and precipitation rate between and within populations of a single *Pan* subspecies. Our approach bears great potential supporting palaeoenvironmental and dietary reconstructions in fossil hominins.

**Keywords:** primates, diet, environment, wear facets, surface texture

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# Hardness of the root dentine: a comparative study of Human primary and permanent mandibular incisors

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Knowledge of physical properties of the dentine is essential for understanding age- and disease-related alterations of the tooth. The aims are to compare hardness of the dentine forming roots of primary and permanent teeth and to identify possible differences between dentine layers and root surfaces. A sample of 11 primary and 14 permanent caries free mandibular incisors was selected from collection of extracted teeth. Roots were sectioned transversely below the cemento-enamel junction, embedded in epoxy resin and polished metalo-graphically. Vickers hardness (HV) was determined with a universal indenter (Shimadzu, Kyoto, Japan) by applying 100g force for 10 seconds. Measurements were made at regular intervals from the cemento-dentinal junction to the root canal for each of the root surfaces. A Student's $t$-test for independent samples and one-way ANOVA followed by post-hoc comparison with Tukey's (HSD) procedure were used to analyze the data. On average, the root dentine was harder in permanent than in primary teeth (68.9 HV vs. 62.1 HV; $p < 0.001$). The results show that hardness of the circumpulpal dentine (CD) tends to decrease with proximity of the pulp, both in primary and permanent teeth. Hardness of the mantle dentine deviated from this rule; in both groups of teeth it was lower than for the outer third of the CD ($p < 0.001$) and in primary teeth even lower than for the middle third of the CD ($p < 0.001$). In permanent teeth, the dentine was harder on approximal root surfaces (mesially 71.0 HV, distally 74.1 HV) than on labial (67.1 HV) and lingual surfaces (66.0 HV) ($p < 0.001$). The results may reflect mineralization differences between primary and permanent teeth, increased dentinal tubule density observed on approaching the pulp, hypomineralized nature of mantle dentine and physiological (age-related) sclerosation of dentinal tubules in permanent teeth.

**Keywords:** Vickers hardness, dentine, root, primary teeth, permanent teeth

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# A new method for determining the 3D spatial orientation of molar microwear

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Many types of behavioral and dietary information can be extracted from studies of tooth microwear. However, microwear has never been successfully and non-destructively visualized in-situ in 3 dimensions (3D), visualized virtually and quantified. The ability to accomplish this yields information on exact masticatory movement which can then be used to address any number of eco-biological and eco-dietary questions in extant and extinct organisms. In order to create 3D virtual reality (VR) representation of functional microwear, molars from the Javanese Sangiran 7 (S7) *Homo erectus* tooth collection (n=25) and from historic hunter-gatherer meta-populations (Inuit (n=9), Pacific Northwest Tribes (n=11), Fuegians (n=11), Australian Aborigines (n=12) and Bushman (n=20) were imaged using a white-light 3D scanning system (smartSCAN 3D, Breuckmann GmbH; resolution of 55 µm) to produce topmetric VR reconstructions of each tooth. The microwear for selected cusp facets (3, 6 & 9 preferentially) were then imaged using a K2S Bio portable confocal microscope (Technical Instrument Co. Sunnyvale, CA; Bromage US Pat. App. No.: 10/960,325, OIL Id. No.: BRO03-01PRO.). This 3D microwear information, defined as facet microwear vector (fmv's) signatures, was then placed back on the topometric VR representations of the molars using a combination of PolyWorks® 10.1 (a 3D model editing software package; InnovMetric Software Inc.) and Rhinoceros ® 4.0 NURBS modeling software (McNeel). This was then quantified using an algorithm specifically designed to automatically cross-compare multiple fmv signatures and define relatedness based upon a weighted 'match' number. The methodology contained herein demonstrates the efficacy and importance of such a technique in determining gross masticatory movement in fossil and recent hominin molars. This methodology could, in theory, be applied to any organism which produces microwear on its dentition. Applications in the fields of dentistry, orthodontics, climatology and dietary and habitat reconstructions can also be envisioned.

**Keywords:** *Homo erectus*, microwear, 3D imaging, paleodiet, mastication, paleodontology

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# Putting 3D dental topography into practice: the dental tools of a Pliocene colobine monkey, *Dolichopithecus ruscinensis*

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From a form-function perspective, the occlusal morphology of mammalian teeth results from a compromise between dental occlusion and the necessity to deal with food. More precisely, general morphology guides lower teeth when they occlude with upper teeth, while fine morphology, akin to "dental tools", reduces and fragments the food. These dental tools may be characterized using 3D dental topography, a recent and reliable approach that describes dental surfaces, such as outer enamel surface, as complex polygonal meshes. Assessing dental tool-like adaptations from outer dental topography might be especially useful for the study of dietary behaviors in extinct species, as some are only known from their teeth. Here, we characterize the topography of 40 unworn upper molars scanned from the skulls of extant cercopithecoids. Using three kinds of topographic variables related to relief, sharpness and orientation, we graphically separate longitudinal crests, that act as shearing tools in this group, from transverse crests or lophs that act as occlusive guides. Furthermore, we use this methodology to isolate the dental tools of an extinct colobine monkey, *Dolichopithecus ruscinensis* from the Early Pliocene of Europe. Comparisons with extant specimens indicate that the longitudinal crests of *D. ruscinensis* were low and long, while its lophs were wide and tall. However, the molars of *D. ruscinensis* were moderately sharp, with high relief but low complexity. To some extent, this is similar to what is observed in *Cercopithecus campbelli*. This is consistent with earlier descriptions of *Dolichopithecus* as a terrestrial, probably not folivorous colobine monkey.

**Keywords:** complexity, Colobinae, paleoecology, relief, sharpness

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# Variation of the human mandible shape is a matter of allometry and secondarily, of diet

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The causes of facial variability among human populations have been linked to environmental and genetic factors. Variation in bite forces exerted on the teeth due to diets of different consistency is thought to play an important role, but the extent of this effect is still under debate. The aim of this study is to describe global and localized effects of diet consistencies on mandibular shape. Using three-dimensional geometric morphometric tools, we compared the shapes of 90 mandibles from living individuals and osteological collections from current Chilean and Argentinean territories. They had different subsistence strategies resulting in three main diet consistencies: hunter-gatherers (hard/tough), agriculturalists (intermediate) and urban groups (highly processed, soft diets). Individuals included had almost all their teeth, and at least two molars located in a functional position. Each mandible was reconstructed from a computed tomogram, and 32 bilateral landmarks were placed on them. An allometry test showed a significant relationship between shape and size, with smaller mandibles having slender mandibles with more open gonial angles and larger mandibles showing more robust features, a closed gonial angle and more vertically oriented condyle and coronoid processes. Groups cannot be clearly differentiated along the regression line, although hunter-gatherers tend to have the largest mandibles. Allometry also explains most of the variance in a principal component analysis, with diet as a secondary factor. Groups, however, do differ in their overall morphology, as shown in a MANOVA test, but less markedly between hunter-gatherers and agriculturalists. The allometric pattern agrees with the classic description of mandibular development. These results indicate a primary role of bone growth in shaping the human mandible. However, the importance of functional loads should not be disregarded; more intense masticatory loads are likely to induce full mandible growth.

**Keywords:** mandibular shape, diet consistency, geometric morphometrics, allometry, growth

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# 5. Odontology and paleodontology

# Population characterization based on dentin trait: lower second premolar transverse crest

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The enamel-dentin-junction (EDJ) carries valuable taxonomic information that can be used to define and characterize populations. Yet, most of the morphological traits utilized in the anthropological research (e.g. ASUDAS and geometric morphometric analysis) are based on the outer enamel surface, which is more subjected to attrition and environmental changes. Transverse crest in the lower second premolar was previously described as an enamel feature, which presented morphological variability between populations. The purpose of the current study was to define and analyze the transverse crest trait in the dentin layer using 3D geometric morphometric methods. 89 lower second premolars were segmented from micro-CT volume data in Amira 6.3 (FEI, Germany) to obtain 3D digital surfaces of the EDJ. The transverse crest shape was subsequently digitized in the EVAN Toolbox 1.71 (ET, http://evan-society.org), using 12 equally spaced sliding semilandmarks along the curve connecting two anatomical landmarks: protoconid and metaconid dentin horn tips. Two additional landmarks were placed in the deepest points of mesial and distal fossae to describe the relative position of transverse crest on the occlusal surface of EDJ. All gathered coordinates were superimposed using Generalized Procrustes Algorhitm (GPA), following by a Principal Component Analysis (PCA) to examine shape variation in the sample and the distribution of each group in shape space. The study sample comprised of modern humans from different geographical populations, Upper Paleolithic, early anatomically modern humans and Neanderthals (NEA). We observed a significant separation between the studied populations on the PCA plot of the EDJ transverse crest trait shape. Based on the results, we concluded that the morphology of the dentin transverse crest in the lower second premolar can serve as a reliable trait to distinguish between populations; therefore, it should be considered as a tool for population analysis.

**Keywords:** Dental morphometric, Neanderthals, Anatomically modern humans, lower premolars, transverse crest

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# Dens Invaginatus: a virtual analysis

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Dens Invaginatus (DI), also called "Dens in dente", "Dilated composite odontome", "Gestant odontoma", "Dentinoid in dente" or "Telescopic tooth" is a malformation of teeth, probably resulting from an infolding of the dental papilla during tooth development. Affected teeth show a deep infolding of enamel and dentine starting from the foramen caecum or even the tip of the cusps and which may extend deep into the root. Oehlers (1957) classiffed these defects according to their severity-Type I, confined within the crown not extending beyond the amelo-cemental junction; Type II, an enamel-lined form which invades the root but remains confined as a blind sac. Type III a form which penetrates through the root perforating at the apical area showing a "second foramen" in the apical area. The etiology is controversial and remains unclear. The possible factors responsible are, lateral fusion of two germs, constriction of dental arch in the enamel organ, increased external pressure, focal growth retardation, invagination of the crown before calcification of the teeth. The first purpose of the present study was to review the current literature on this dental anomaly. Then, a micro-CT scan acquisition of a first mandibular premolar "radicular dens invaginatus", allow us, to make 2D and 3D virtual analysis, with high definition, of the various tissue structures constituting this malformation. Indeed, this anomaly is very peculiar because most of the dens in dente are coronal, as described in Oehlers' classification. The secondary objective of this presentation is to propose a predictive and chronological model of the maturation of this rare case of radicular dens invaginatus, to try to understand the formation of this individualized radicular structure, with a layering of varying-density tissues.

**Keywords:** Dens invaginatus, Micro, CT, 2D/3D analysis

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# Basques demonstrate a high prevalence of molar-incisor hypomineralisation (MIH)

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Molar-incisor hypomineralisation (MIH) results in enamel structural abnormalities affecting at least one of the first permanent molars (FPM) and often the permanent incisors. The prevalence of MIH is about 15% in Europe. To date, its aetiology is still unclear, but is likely multifactorial. Hypotheses include pre-, peri-, and post-partum factors. Some researchers have hypothesized that a genetic predisposition or an epigenetic influence may play a role in the development of MIH. Because Basques represent a very old and unmixed European people expressing particularities both in biology and culture, we aimed to assess the frequency of MIH among this population in comparison with the non-Basque neighbours. Population under study: A cohort of children from SouthWestern France aged between 7 to 11 years was prospectively investigated. Individuals were considered as Basques if they had typical Basque surnames and their four grand-parents of Basque origin. Individuals not fulfilling these criteria were included in the non-Basque group. Diagnosis of MIH was based upon EAPD criteria: presence of demarcated opacities (white to yellow-brown), atypical restorations or FPM extraction. Statistical analyses were performed by means of odds ratio and t-test using Statistica® software. 516 children were included in this study whose 231 are autochthonous Basques. The prevalence of MIH was significantly higher in Basques (23%; 54/231) than in non-Basques (17%; 51/285) (p < 0.01). Basques are 1.4 times more likely to develop a MIH than non-Basques (OR = 1.4 [0.91-2.15]). Furthermore this prevalence seems also superior to that observed in the general European population (respectively 23% and 15%). MIH is to be considered as an additional condition which demonstrates an unusual distribution in Basques. The respective roles of intrinsic (genetic) and environmental (epigenetic) factors in the genesis of this phenomenon need to be elucidated.

**Keywords:** Basque, enamel, hypomineralisation, MIH, genetic, etiologies

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# Hypomineralised amelogenesis imperfecta: an X-ray microtomographic study

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Amelogenesis Imperfecta (AI) is a rare group of conditions, genomic in origin, which affect the structure and clinical appearance of the enamel of all or nearly all the teeth in a more or less equal manner. Patients with hypomineralised AI have discoloured teeth that are rough and susceptible to breakdown and sensitivity. X-ray microtomography (XMT) is a non-destructive imaging technique that allows quantification of changes in mineralisation and has the ability to study structures in 3D. The aims were to quantify mineral concentration in 3D in hypomineralised AI and to examine gradients from natural surface to enamel dentine junction (EDJ) using XMT. Two AI premolar teeth were extracted for orthodontic purposes and scanned using XMT (resolution = 30 m, 1mm diameter aluminium wire as internal calibration). Mineral concentration was determined from the linear attenuation coefficient assuming the mineral phase in hydroxyapatite ($\rho$ = 3.15gcm-3). In addition, five normal premolar teeth were scanned as controls. For the control teeth, the mean mineral concentration of enamel was 2.825 gcm-3 (s.d. = 0.023) and the mean enamel volume was 132.6mm-3 (s.d. = 2.51). For the two AI teeth, the mean mineral concentrations of enamel were 2.57 gcm-3 and 2.56 gcm-3 and enamel volumes were 123.1mm-3 and 118.3mm-3 respectively. For the control teeth, the mean mineral concentration at the EDJ was 2.73gcm-3 (s.d.=0.07) and at the natural surface was 3.01gcm-3 (s.d.=0.05). The gradient was linear. For the AI teeth, the mean mineral concentration at the EDJ was 2.37gcm-3 (s.d.=0.1) and at the natural surface was 2.49gcm-3 (s.d.=0.1). The gradient within the AI teeth was variable with lowest mineral concentration found in the centre of the enamel rather than at the EDJ. XMT can be used to quantify and 3D map mineral concentration in hypomineralised AI teeth.

**Keywords:** amelogenesis imperfecta, hypomineralisation, x-ray microtomography, mineral concentration

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# Further evidence of an unusual dental enamel alteration in prehistoric Italian populations

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An unusual modification of the dental enamel surface was observed and described, for the first time, in an Early Bronze Age population from northern Italy (Arano, Verona). The alteration is similar to a curvilinear groove located on the lingual surfaces of incisors and canines in the upper jaw. This lesion is situated a few mm from the cervix and extends from the mesiolingual to the distolingual surface. After recording this feature in the Arano population, its occurrence in other prehistoric samples has been investigated. This enamel defect is alike, in appearance, to those observed in other prehistoric population from Italy, as Favella di Sibari - Cosenza Calabria (Neolithic), Corna Nibbia di Bione - Brescia, Lombardia (Eneolithic), Garavicchio - Grosseto, Tuscany (Eneolithic), Ponte S. Pietro - Viterbo, Lazio (Eneolithic), Grotta del Fontino {Grosseto, Tuscany (Eneolithic/Bronze Age), Sorbara di Asola - Mantua, Lombardia (Early Bronze Age) and from Europe, as Franzhausen I -Lower Austria (Early Bronze Age), until now undocumented. The dentition of all the individuals of these skeletal samples was analyzed to determine the frequency and the possible etiology of this lingual modification. The observations included groove morphology, position and association with dental pathology. Some teeth were also analyzed under a scanning electron microscope to better understand the nature of this alteration. Because of its morphology, the groove cannot be considered as a result of disruptions in the process of enamel deposition, but probably the result of some kind of chemical erosion occurred in vitam. The cause of this unusual alteration remains unknown.

**Keywords:** Lingual groove, upper anterior dentition, Prehistory, Italy

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# Dental morphological evidence for circum-mediterranean population relationships and implications for mestizos in North America

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History tells us that Spain was the primary contributor of European genes to the Mestizo (including American Hispanic) population of Mexico and the United States. But, what are less understood are origins of the Spanish themselves. Which populations, and in what proportions, were contributors to the Spanish of 1492 and later, who left Europe to invade North America? In the paper we address this question using evidence from dental morphology, which provides phenetic evidence of population admixture. The sample consists of 65 dental morphological observations representing 10 European and 13 African countries (n=3552) from the 9th century to the present. These data were analyzed using biological distance measures, multi-dimensional scaling, and admixture analyses to understand within and between group patterns of variation. We find that Medieval Northern Spanish differ significantly from contemporaneous Southern Spanish. Northern Spanish cluster more closely with samples from France and Germany, while Southern Spanish cluster more closely with several circum-Mediterranean samples. We examine these findings in the light of history and geography. Finally, we include a discussion of how circum-Mediterranean admixture that existed prior to 1492 influenced the genetic make up of admixed people in North America.

**Keywords:** Dental morphological characteristics, Biological distance, Admixture analysis, Spain, Mestizos

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# Dental tissue proportions of European and African populations: sexual dimorphism

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Accurate sex estimation is an essential step for the reconstruction of the biological profile of the human remains. Previous research showed that elements of the human permanent dentition are sexually dimorphic. The aim of the present study is to assess the dental tissue proportions of modern human permanent mandibular canines, in order to identify the sexual variability present in two populations from different geographical origin. Our sample consisted of a total of 53 mandibular permanent canines of known sex from Europe and Africa. Bucco-lingual sections of the crown were obtained and the different metrics described by Martin (1983) were recorded using the methodology devised for canine teeth by Feeney and colleagues (2010). Our results corroborate that sexual dimorphism in dental tissues proportions is due to males having an absolute greater amount of dentine, as well as females having a relative greater and thicker enamel cap area, which is hidden behind the crown size differences between males and females. The histological patterns differ depending on the ancestry of the individual, although the sexual dimorphism of both populations separately is similar to those of the whole sample. The coronal dentine and pulp area was relatively greater in the European sample, as well as a larger relative EDJ length. However, African population had, absolutely and relatively, greater enamel cap area. This study results support that sexual dimorphism of dental size is mainly due to male's greater amount of dentine, whereas enamel differences not making a large contribution to overall tooth size dimorphism. Moreover, the geographical origin of the individuals in the sample should be a factor to take into account in the assessment of the sexual dimorphism from histological patterns.

**Keywords:** Dimorphism, canines, dentine, enamel, microtomography

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# First cases of enamel hypomineralisation amongst past populations: a new approach in understanding MIH etiologies

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Molar Incisor Hypomineralisation (MIH) and Hypomineralised Second Primary Molars (HSPM) involve prevalent qualitative structural developmental anomalies of tooth enamel affecting the first permanent molars (and often incisors) and the second primary molars, respectively. These demarcated hypomineralised lesions of enamel manifest as white-cream or yellow-brown opacities. Etiological hypotheses have involved contemporary life factors (i.e. environmental pollutant exposure or early childhood medications) in contrast to factors not limited to a specific time period (i.e. hypoxia at birth or genetic predisposition). Evidence of MIH in ancient populations would reinforce etiological factors present for many centuries. Microtomography provided information on mineral densities. X-ray fluorescence provided information on taphonomic contamination by one or several chemical elements (Mn, Fe, Cu and Pb). Analyses were performed on three archaeological specimens showing demarcated discolorations: S407" (Sains-en-Gohelle, France, 12th-16th centuries), "B335" (Beauvais, France, 15th-18th centuries) and S323" (Sains-en-Gohelle, France, 7th-11th centuries). Wilcoxon test for paired samples were carried out using Statistica® software to compare data from normal and discolored enamel. Our results showed a poor agreement between the 19 examiners (MIH experts) concerning MIH clinical diagnosis due to taphonomic (post-mortem discoloration) bias (Fleiss' < 0). All teeth with discolorations had significantly lower mineral densities in discolored enamel ($P < 0.05$). Some discolorations on teeth were characterized by an increase in Mn (respectively, $P = 0.01$ and $0.04$) or an increase in Fe ($P = 0.01$). Other teeth did not show evidence of a taphonomic contamination by these elements ($P > 0.05$). The present study provides evidence that (i) two archaeological specimens: "S407" and "B335" were MIH-affected, and (ii) one individual "S323" was affected by HSPM and MIH. Our results highlighted factors not limited to a specific time period (i.e. hypoxia at birth or genetic predisposition).

**Keywords:** enamel, hypomineralisation, MIH, HSPM, taphonomic discoloration, etiologies

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# Periodontal disease in the Portuguese identified skeletal collections from the late nineteenth and early twentieth centuries: comparison between Central and Northern Portugal

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The aim of this study is to compare the pattern of prevalence and distribution of periodontal disease between two samples of Central and Northern Portugal belonging to the identified osteological collections curated at the University of Coimbra, Portugal, dating back from the late nineteenth and early twentieth centuries in order to determine whether factors such as age-at-death, sex, tooth type and geographical region should be considered in future archaeological studies. Periodontal disease was investigated in 600 adult dentitions from Central Portugal and 151 from Northern Portugal. The periodontal status was recorded using Kerr's 6-category assessment of the interdental septum and the extent of bone loss. Individuals with a minimum of 15 interdental septal areas were included in this study. The frequency of periodontitis in Central Portugal was 73.8% and in Northern region was 90.8%. A significantly higher frequency of periodontal disease, independent of age, was found among males compared to females in Central Portugal. No significant differences were found between the sexes in Northern Portugal. Gingivitis was widespread in the younger age groups in both sampled areas. Destructive periodontitis was observed early in adulthood, rising steadily with age and having no geographical differences. The most susceptible sites to periodontal breakdown were similar and located in the posterior region of the upper jaw. The differences found in the frequency and distribution of periodontal disease in the two Portuguese regions can be due to variations in socio-behavioural conditions and/or diet. The results suggest that contextual factors contribute to periodontal disease and help explain geographical inequalities among Portuguese adults. Therefore, it is concluded that factors such as age-at-death, sex, tooth type and geographical region should be considered whenever possible in future periodontitis studies in archaeological samples.

**Keywords:** Dental anthropology, paleopathology, periodontitis, Coimbra, Portugal

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# Estimating ancestry proportions in African American samples using dental morphology

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Scholars examine admixed human populations in order to redress the social consequences of racism and to identify the genetic components of multifactorial disease. In recent years, geneticists have refined the methods used to estimate ancestry in admixed populations. These methods have yet to be applied to morphological data. Our goal is to use a widely-used method to estimate African and European ancestry from dental morphology and genetic data in admixed African Americans (AA). The dental data are 62 dichotomized morphological traits from 664 AA, 335 Europeans, and 307 Africans. The genetic data consist of 1,022,144 autosomal single nucleotide polymorphisms (SNPs) for 49 AA, 110 Europeans and 112 Africans. To assess informativeness for ancestry estimation, we calculated Fisher Information (FI) for all markers in each data set. We then estimated individual ancestry using the model-based clustering algorithm implemented in STRUCTURE. The average per-trait FI was higher for the dental data (0.88 vs. 0.36), but the genetic data contained thousands of markers with more information that the most informative dental trait, and the total FI was 7,000 times greater (354,566 vs. 50). In the admixture analyses, results for the dental data were comparable to those achieved with 10 SNPs: the African and European samples failed to form distinct clusters, though the mean African ancestry was highest in the African sample (65%), lowest in the European (24%), and intermediate in the AA (55%). In contrast, in analyses of the full SNP dataset, African ancestry was 97% in the African sample, 1% in the European, and 74% in the AA. These values accord well with other genetic analyses. These results imply that methods used to estimate individual-level ancestry for genetic data are poorly suited to dental morphology, though they may have the potential to distinguish large differences in mean ancestry levels among admixed populations.

**Keywords:** admixture, dental morphology, African Americans, Fisher information, STRUCTURE

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# Bilateral presence of radix entomolaris in first and second permanent mandibular molars identified in a Caucasian woman: a case report

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A healthy Caucasian girl aged 12 years was referred to the dental clinic by a general dentist who failed to completely instrument canals in the mesial and distal root of tooth 36 (FDI system). In the first session, supernumerary root radix entomolaris (RE) was identified and cone-beam CT (CBCT) scan was taken. Afterwards, several ledges in the root canals were successfully negotiated and treatment was completed in the third session. CBCT revealed the presence of RE also on tooth 37 and deep longitudinal grooves and C-shaped canal pattern in roots of both neighbouring premolars. Additionally, panoramic radiograph indicated the presence of RE on the contralateral first and second molars. Roots of mandibular third molars have not yet been developed. Clinically, the crowns of both mandibular second premolars were mesiodistally enlarged; the right one exhibiting four cusps and the left one exaggerated marginal ridges. Individuals with bilateral RE on first and second mandibular molars are extremely rare, especially in ethnic Europeans who have a low prevalence of this radicular trait. To our knowledge, the unilateral presence of RE in both aforementioned teeth has been so far documented in two patients, one of Chinese and one of Indian descent; however, researchers failed to mention this in text. In another Indian patient, right first and left second mandibular molars were affected. Development of RE and a tendency of mandibular premolars to increase the root number may be associated. Observations also indicate that in mandibular premolars, atypical coronal enlargements may be accompanied by increased differentiation of the root.

**Keywords:** radix entomolaris, first permanent mandibular molar, second permanent mandibular molar, mandibular premolars, dental morphology

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# Consideration of tooth loss in ancient Japanese

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Dentition continuously proceeds to an edentulous condition over time. Also, it can be capture as continuously condition without interruption. The causes of tooth loss include caries, periodontal disease, bruxism, and others, though it is difficult to determine the cause of lost teeth in ancient people. Knowing the process of tooth loss helps to consider the living environment of ancient people. Skulls dating from the end to last of the Jomon period (4500-2800BP) were examined to determine remaining teeth and occlusal support areas, and caries. Cummer's classiffication was used to evaluate remaining occlusal support areas. We carried Chi-square test and GLM (generalized linear model). In 78 skulls without destruction of the maxilla or mandible, evidence of defective dentition was seen in 28. In those with a partially edentulous arch, a missing lower anterior tooth area was most often seen (n=14). In skulls missing posterior tooth areas, 1 was missing only the upper area, 1 only the lower area, and 3 both areas. Caries occurrence was noted in 53.6% and 26.0% with a partially edentulous and non-edentulous arch, respectively. The odds ratio of tooth loss with the presence of caries was 3.28. Also in GLM, it is speculated that the tooth loss increase with the presence of caries. Only 35.9% of the examined Jomon skulls had a partially edentulous arch, in which the rate of caries was significantly higher. Therefore, caries was considered to be a major cause of tooth loss in these people. In addition, no difference between the upper and lower missing posterior tooth areas was observed. In contrast, in modern people, a tendency to lose upper jaw teeth more often has been reported. It is considered that there was little influence of periodontal disease in Jomon period.

**Keywords:** Tooth loss, Cummer's classi cation, Partially edentulous arch, Ancient Japanese (Jomon), Dentition

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# Periapical abscesses and suppurative osteomyelitis of the jaws due to failure of dentin formation in Baltic grey seals (*Halichoerus grypus grypus*) from the 19th century

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We studied five skulls (3 complete, 2 fragmentary; housed in the collection of the Natural History Museum of Denmark) of juvenile Baltic grey seals that had been collected in 1889/1890 in three locations along the coast of the southern Baltic Sea. All specimens showed a similar spectrum of pathological dental and osseous changes. Thus, all canines and most of the incisors available for examination exhibited openings into the pulp cavity at their occlusal (incisal) tips. Macroscopic and radiographic inspection revealed that the walls of these teeth were very thin and their pulp cavities abnormally wide. In one specimen, also three maxillary premolars showed the condition. In all these cases, apparently a failure of dentin formation had occurred following the initial deposition of a thin layer of (mantle) dentin. Exposure of the pulp had caused its infection and in ammation. Presence of radiolucent areas around the root tips of the affected teeth indicated that the process had spread from the pulp through the apical foramen into the periapical space, causing the formation of periapical abscesses and bone resorption. Pathological changes were particularly severe in canines, which are deeply inserted in the jaws and whose root tips were surrounded by extended abscess cavities. From the periapical regions the infection spread into the adjacent jaw bones, causing a severe suppurative osteomyelitis. Evidence for this were extensive bone resorption and occurrence of numerous bone-perforating draining tracts in the skulls, and the presence of sequestra and involucra in two of the mandibles. As the described condition occurred within a rather narrow geographic area and a short period of time, it is hypothesized that the dentin abnormality (dysplasia) observed in all five grey seals had a hereditary background.

**Keywords:** dentin, grey seal, periapical abscess, pulp exposure, osteomyelitis

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# Enamel hypoplasia in Melolo prehistoric people Indonesia

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Excavations in the area Melolo, East Sumba, Indonesia, which were held in the 1930s, discovered 19 human skeleton buried in Urn (2870 60 BP). From 19 human remains that were discovered, there are three individuals who displayed enamel hypoplasia (EH). EH are useful indicators of systemic disturbances during childhood growth, and are routinely used to investigate patterns of morbidity and mortality in past populations. The purpose of this study was to describe the appearance of EH and the emerging of other diseases in the same individual. Macroscopic observations were used to determine the sex and age of the individual using standard methods. Then all human remains were identified to assessed disease or pathological signs. A total of 32% of the human remains displayed cribra orbitalia and porotic hyperostosis. Two of the three individuals who have indicated EH also have infectious diseases (leprosy). This indicates that EH plays an important role in the welfare and health conditions.

**Keywords:** Enamel Hypoplasia, infectious disease, Melolo, Indonesia

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# First description of partially digested Neandertal teeth, experimentation, results and other new discoveries

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Excavations at the Middle Palaeolithic site of Les Pradelles (southwest France) resulted in the recovery of Quina Mousterian lithics, fragmentary Neandertal remains (infra-cranial, cranial bones and isolated teeth) from adults and juveniles, and many reindeer long bone fragments in addition to bones of other mammals, including carnivores. Analysis of the excavation records suggests that the site was used by Neandertals as a hunting camp at the base of the stratigraphy and later as a carnivore den. A re-examination of the faunal sample resulted in the discovery of two Neandertal permanent incisors which had previously been identified as deciduous incisors of a bovid or a cervid. They exhibit atypical features of the crown and root that are more characteristic of deciduous teeth, yet possess the crown anatomy of permanent teeth. Additional field discoveries have resulted in the further accumulation of almost 20 (permanent, deciduous) human teeth or germs (upper and lower canine, premolar, molar), that present the same atypical morphology. Teeth from hyena dens and experimentation demonstrated that only the action of carnivore digestive enzymes and acids could have resulted in the morphology present on these teeth. Here we will (i) describe the partially digested teeth and discuss the main features that make their identification as hominin difficult and (ii) discuss the results of our work documenting the action of carnivore digestive activities in modifying the morphology of the teeth. Other sites in France have also yielded hominin teeth that present similar morphological modifications. From the literature, there also appears to be teeth with similar attributes from Plio-Pleistocene sites in South Africa, although they apparently have not been recognized. An obvious implication of this work is that more attention should be directed toward faunal samples from locales where large predators may have been involved in their accumulation.

**Keywords:** Neandertal, carnivore digestion, taphonomy, Mousterian

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# Oligodontia: congenitally missing of eight permanent teeth. A case report

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Hypodontia is a dental anomaly related to one to six congenitally missing teeth. One of the most frequent dental anomalies, its prevalences is between 2.7%-11.3% in different populations. The most frequently missing permanent tooth (excluding the third molar) is the mandibular second premolar, followed by the maxillary lateral incisor, the maxillar premolar and the mandibular central incisor. Oligodontia, a developmental anomaly involving six or more missing teeth, is less common, while anodontia, a complete lack of development of the deciduous and/or permanent dentition is an extremely rare condition. The prevalence of oligondontia is around 0.25% in European populations. Multiple missing teeth are usually associated with genetic disease but can also be found as an isolated trait, in a non-syndromic form. We are presenting a case study of a 20 year old woman with eight congenitally missing permanent teeth. The patient requested aesthetic dental rehabilitation at the age of 17. A detailed clinical interview revealed previous orthodontic therapy with mobile appliance with no satisfactory results. There was no family history related to hypodontia or other dental anomalies. During intraoral and radiographic examination, the following permanent teeth were found missing: the maxillary lateral incisors and first premolar, the mandibular central incisors, the lower left lateral incisor and the right first premolar. A multidisciplinary approach in treatment was planned with orthodontic, surgical and fixed prosthetic solution. Fixed orthodontic therapy was undertaken for two years in both the upper and lower jaw, in order to establish Angle's Class I occlusion and to create favorable conditions for the correct replacement of missing teeth based on an implant-prosthetic solution. The main problem with implant planning and placement was very thin alveolar bone and need for significant bone augmentation. The treatment is still ongoing, with four implants replacing lateral maxillary and central mandibular incisors.

**Keywords:** Hypodontia, Oligodontia, Tooth agenesis, Permanent dentition, Dental rehabilitation

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# A case of dental erosion in an subadult individual exhumed at Pedra do Cachorro archaeological site (Pernambuco, Brazil) during the Late Holocene

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The extremely well preserved skeleton of a child with an approximate age of death of 4 years was found in Pedra do Cachorro, an archaeological site located in the Pernambuco hinterland, northeastern Brazil and dated to the Late Holocene (1470 +/- 30 B.P.). Although there is no evidence of pathologies in postcranial skeleton, the maxillary teeth of this subadult individual present strong evidence of enamel and dentin wear due to intrinsic acid erosion, strongly suggesting the presence of a gastric disorder causing frequent episodes of vomiting or gastroesophageal reflux. The gastric pathology may or may not be linked to the cause of death of this infantile individual. This common dental pathology found in the modern times, is a rare case of paleodontology disease revealed in archaeological material of native American populations before European contact.

**Keywords:** Dental anthropology, Dental erosion, Gastric disorder, Gastroesophageal reflux, North-eastern Brazil

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# The prevalence of three-rooted permanent mandibular molars in a slovenian population

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Three-rooted permanent mandibular molar (3RM) is a root trait with great clinical significance and interesting geographic distribution. Nevertheless, studies on the prevalence of 3RM in European populations are sparse and mostly limited to the first molar. The aim of this retrospective study was to assess the prevalence of the third root in all types of mandibular molars among a Slovenian dental school patient population. The dental records of patients visiting students and interns in the Centre for Operative Dentistry and Endodontics during the last 10 years were screened. 1318 patients (609 males and 709 females) possessing intraoral (periapical or bite-wing) radiograph of at least one permanent mandibular molar were selected. These radiographs were evaluated independently by two observers under optimal conditions. The prevalence of the third root in different types of mandibular molars and the correlation between left- and right-side occurrences and between males and females were recorded and analyzed using the chi-square test. A total of 3672 mandibular molars (1361 first, 1575 second, 736 third) were evaluated. The overall prevalence of 3RM was 1.0% (1.3% for the first molar, 0.3% for the second molar, and 1.8% for the third molar). There was neither a significant difference according to sex, nor the side of occurrence (left vs. right side) in any type of mandibular molars ($p > 0.05$). Relatively low prevalence of 3RM in a Slovenian population is in agreement with available data for Europeans. The third root occasionally develops in all types of permanent mandibular molars; however, this occurs least frequently in the second molar. The clinician should always consider the possibility of 3RM even when treating European patients.

**Keywords:** dental morphology, permanent mandibular molars, accessory root, radix entomolaris, radix paramolaris

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# Dental traits of Skolt Sami

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Skolt Sami (formerly Lapps) are an indigenous population of Northern Scandinavia. They inhabited Western parts of Kola Peninsula for centuries until they volunteered to move to the Finnish side after World War II. Due to the small population size (< 500), limited mate choice and geographic isolation, inbreeding was common, index representing a value between half second cousin and full third cousin (0.0045). The study of Kirveskari et al. (1974) showed that Skolts' combination of dental traits wasn't typical either of the Mongoloid or Caucasoid form, but suggested more Caucasoid than Mongoloid origin. Shoveling of the incisors varied significantly in subpopulations and showed significant sexual dimorphism in upper lateral incisors in the whole population, women being the majority. Skolts showed labial ridging (double shovel) more often than expected, based on the degree of expression of the lingual shovel trait. Forty per cent of Skolts showed finger-like projections on lingual surfaces of the upper incisors and canines. Skolts and half-Skolts (o spring of Skolts and mostly Finns) showed significant difference in second molar hypocone reduction. Skolts showed predominantly negative expression of the Carabelli trait, positive expressions were rare. Other accessory cusps were more common in Skolts than in half-Skolts. Dental caries prevalence was high and total loss of teeth was common due to unsatisfactory oral hygiene and caries. Frequent loss of teeth increased the frequency of tipped and rotated residual teeth. Enamel hypoplasias were frequent along with hypodontia, as more than 5% of the Skolts had 1 to 4 missing premolars and molars. Long genetic isolation, drift and natural selection probably explain why the morphological reduction of teeth commonly seen in Caucasoid populations is marked only in the posterior teeth of the Skolts.

**Keywords:** Skolt Sami, dentition, dental morphology, genetic isolation, physiological adaptation

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# Dental development of the Neanderthal child from Subalyuk (Hungary). Anomalies of tooth shape and dental arch relationship

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The Subalyuk human remains were uncovered in 1932 in a cave located nearby the Cserepfalu village in the Borsod country, in Northern Hungary. They represented two individuals, an adult and a child about 3-4 years old at death that were, since their discovery, described in a few publications providing substantial anthropological data and general assessments about Neanderthals. The remains of Subalyuk 2 child consist of the neurocranium, the maxilla, the left isolated nasal bone and few vertebral bodies. On the maxilla, 8 deciduous teeth (right central and lateral incisors are missing) and germs of first permanent molars are preserved. The computer-assisted virtual reconstruction of the bone reveals the presence of 7 additional germs of permanent teeth. Developmental stages are recorded for each tooth and discussed. The developmental anomaly of form in the right deciduous canine, originally noticed by Brust, favours the diagnosis of gemination. In extant populations, cases with double primary anterior teeth (both fusion and gemination) occur most frequently in the maxilla than in the mandible, but with a prevalence that does not exceed 1.6%, with no sex prediction. While the aetiology of gemination is unknown, the Subalyuk 2 case is unique among Palaeolithic children and the earliest identified, that can be discussed in relation to other dental arch peculiarities of the child.

**Keywords:** dental development, 3D virtual reconstruction, Subalyuk, Neanderthals

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# 6. Tooth evo-devo

# Ontogenetic modifications of dental shape recapitulate ancestral tooth character states in Lagomorpha

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Cheek teeth have changed considerably during lagomorph evolution, from rooted to unrooted evergrowing teeth, with an increase in the crown height and modifications of the occlusal morphology. The adult upper cheek teeth of extant lagomorphs are characterized by the presence of two lophs separated by an enamel fold. We observed that the juveniles and adults have different morphologies of their occlusal surfaces. In order to characterize changes in dental morphology related to age, we studied the morphological variability of cheek teeth in different species of lagomorphs specimens from birth to adulthood. Using X-ray microtomography we were able to extrapolate the occlusal surface at different wear stages by making virtual sections of 3D tooth reconstitutions. We demonstrate that lagomorph upper cheek teeth have a crescent valley structure when the tooth is unworn, which disappears by wear a few weeks after birth, associated with an increase of the re-entrant fold invagination. This fold is initially smooth in juveniles but can become increasingly crenulated with age in some species. Furthermore, the chronology of the morphological modifications occurring during dental development corresponds step by step to what is observed between basal and derived species of lagomorphs. This observation leads us to hypothesize of a peramorphic dental evolution of lagomorphs with a recapitulation of ancestral character states during ontogeny.

**Keywords:** Evolution, Development, Lagomorpha, Ontogeny, Peramorphosis

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# Reactivation of evolutionary lost molar replacement in mice

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Dental replacement is a common process among vertebrates. Many non-mammal vertebrates have a highly dynamic dentition in which teeth are constantly replaced throughout the animal's lifetime. In contrast, only three genera of mammals can replace their teeth all along their life and all others have a maximum of two sets of teeth, the decidual and the permanent dentition. The mouse, which is commonly used as a laboratory model to study mammalian development has only one evergrowing incisor and three molar in each dental quadrant, none of these teeth is being replaced. From the fossil record, we can date the onset of molar non-replacement in mammals at about 205 million years ago, just at the end of the Triassic period. We studied molar rows of mutant mice of the FGF (Fibroblast Growth Factors) pathway and we provide evidences of replacement molar development. We also describe a mouse from a wild population, which phenocopy the studied laboratory mice and present evidences of molar replacement. Our results show that the potential for molar replacement is conserved in mammals and can be reactivated by mutation, in laboratory conditions or in wild specimens. These results would also suggest that the regular molars of mammals are deciduous (milk) teeth that never become replaced.

**Keywords:** Dental replacement, Mouse, Development, FGF pathway, Molars

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# Super-sizing teeth: from mice to elephants

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The sizes of the majority of organs scale with the body size - larger bodies require larger organs. Because all the common model organisms are relatively small, it remains unclear how size affects the mechanisms of patterning and morphogenesis. The mammalian molar tooth is a good example of an organ that scales with the overall body size. Several experimental attempts to alter molar size have led to changes in both size and shape. However, the evolutionary history of mammals shows that size and shape of molars can be decoupled during development. To examine how molar size is scaled much beyond the size of model species, we analysed the patterning of tooth cusps in the largest extant terrestrial mammal, the African elephant (*Loxodonta africana*). Developmental data and computational modelling show that the morphology of *L. africana* molars results from a similar iterative patterning mechanism as in the mouse, but that the patterning happens in a very large size. Our comparisons of several species show that the molar size during patterning is connected to the adult molar size through a seemingly universal relationship. This 'scaling rule' can help to unravel the mechanisms of the interplay between size and shape during molar development.

**Keywords:** morphogenesis, scaling, patterning, elephant, size

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# Connecting prisms and tubules: the 3D relationships of enamel spindles revealed by nanometer scale synchrotron imaging

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There is a lack of evidence regarding the function, formation, and spatial and developmental relationships of dentine- and enamel-tubules and enamel prisms. We used nanometer scale synchrotron tomography of fully mineralised teeth, alongside confocal microscopy of developing teeth, to explore 3D relationships between these structures. In developing mouse teeth, dentine tubules form from odontoblast processes facing ameloblasts across the basement membrane. Whereas initially these processes are multiple, separate extensions of each odontoblast, as cells move away from the enamel-dentine junction (EDJ) the processes converge and merge. In mineralised teeth this results in a single dentine tubule appearing to branch into numerous smaller tubules near the EDJ, though they form via convergence, not branching. Each 'branch' continues across the EDJ into the enamel as a tubule, before merging and terminating in bulbous, globular structures; together these structures represent enamel spindles. The globular structures are associated with enamel prisms, and their orientation is usually aligned with the direction of the prism within the complex decussating 3D enamel pattern. These patterns indicate that odontoblasts, via dentine tubules, are in connection with ameloblasts during enamel formation initiation, potentially influencing patterns of enamel microstructure through spindle globule orientation. Finally, we examined corresponding features in the shrew *Sorex minutissimus*, which has enamel tubules running from the EDJ to the enamel surface. Shrew dentine tubules split less than mouse: only two/three 'branches' cross the EDJ per main dentine tubule. Each 'branch' is continuous with an enamel tubule. Enamel tubules are associated with enamel prisms, inside the prism sheath, but there are significantly more prisms than tubules. This suggests that in shrews, with less complex enamel and no prism decussation, the linkage between odontoblasts and ameloblasts via dentine and enamel tubules is less critical for development of the final enamel microstructure than in more complex mouse enamel.

**Keywords:** Enamel, Dentine, Tubule, Prism, Synchrotron

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# Tooth and scale morphogenesis in shark: an alternative process to the mammalian enamel knot system

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The gene regulatory network involved in tooth morphogenesis has been extremely well described in mammals and its modeling has allowed predictions of variations in regulatory pathway that may have led to evolution of tooth shapes. However, very little is known outside of mammals to understand how this regulatory framework may also account for tooth shape evolution at the level of gnathostomes. In this work, we describe expression patterns and proliferation/apoptosis assays to uncover homologous regulatory pathways in the catshark *Scyliorhinus canicula*. Because of their similar structural and developmental features, gene expression patterns were described over the four developmental stages of both tooth and scale buds in the catshark. These gene expression patterns differ from mouse tooth development, and discrepancies are also observed between tooth and scale development within the catshark. However, a similar nested expression of Shh and Fgf suggests similar signaling involved in morphogenesis of all structures, although apoptosis assays do not support a strictly equivalent enamel knot system in sharks. Similarities in the topology of gene expression pattern, including Bmp signaling pathway, suggest that mouse molar development is more similar to scale bud development in the catshark. These results support the fact that no enamel knot, as described in mammalian teeth, can be described in the morphogenesis of shark teeth or scales. However, homologous signaling pathways are involved in growth and morphogenesis with variations in their respective expression patterns. We speculate that variations in this topology of expression are also a substrate for tooth shape evolution, notably in regulating the growth axis and symmetry of the developing structure.

**Keywords:** Enamel knot, Shark, teeth and scales, evo-devo

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# A developmental perspective on the evolution of the dentition of "toothless mammals"

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The mammalian clade *Xenarthra* has a long history in comparative anatomy. The super-order includes the armadillos, anteaters, and tree sloths and is one of the four major lineages of placental mammals recently defined. Since the 19th century, biologists have been fascinated by the morphological peculiarities of the xenarthran teeth and have made some intriguing observations on their development. However, these rarely provide a comparative basis upon which to analyse possible homologies with the morphology of other mammals. Except for edentulous anteaters, xenarthrans are unique among mammals in retaining simplified teeth that are usually without enamel, rootless, homodont, and often reduced in number. For these reasons, it is difficult to determine tooth homologies with other mammals. We will review several previously explored avenues of xenarthran dental development. Using a large dataset of scanned fetuses of xenarthran species, we will contribute new data on prenatal dental ontogeny and identify some developmental criteria with which to identify homologies with other mammalian teeth. Our developmental data for extant sloths directly supports the claim that their lower caniniform teeth are not homologous to canines of other mammals and that upper caniniforms are not homologous between the two extant sloth genera. These results underline that defining dental homologies in extant species remains complex and that, where possible, characters based on dental features should be augmented with developmental data to ensure proper homology assessment. Applied to the tooth row of all extinct sloths, these developmental data support the interpretation that the dental morphology of three-toed sloths is unusual and illuminate a potential ancestral dental formula for sloths.

**Keywords:** "toothless mammals", xenarthra, development, vestigial teeth

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# The outer limits of developmental conservation of mammalian tooth shape

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Hybridization is well known to occur between living taxa. In mammals, hybridization has attracted renewed interest due to paleogenomic evidence that has implicated interbreeding among human taxa. We have investigated whether hybridization between morphologically disparate taxa can produce developmentally stable, intermediate morphologies. We analyzed teeth of two species of pinnipeds Grey seal (*Halichoerus grypus*) and Ringed seal (*Pusa hispida*), together with a unique hybrid specimen between these two species. Grey seals have fang-shaped post-canine teeth with a prominent central cusp and, when present, small accessory cusps. In contrast, ringed seal post-canines have multiple slender cusps. A computational model simulating tooth development was used to explore the developmental and genetic nature of the hybrid morphology. We contrast these results with genome wide comparisons of genetic differences between the two seal species, between humans and Neanderthals, and between other mammalian species known to hybridize. These results are discussed in the context of potential hybridization in human evolution.

**Keywords:** tooth development, genomics, hybridization, seals, humans

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# Does the Patterning Cascade Model explain accessory cusp variation in the hominoid clade?

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Dental variation in molar cusp patterning features prominently in species diagnoses and evolutionary history reconstructions at both macro- and micro-evolutionary levels. However, the developmental mechanisms behind this variation within the hominoid lineage have been largely unexplored. Here we investigate whether the Patterning Cascade Model (PCM) of tooth morphogenesis explains molar crown differences within our own species, *Homo sapiens*, as well as variation in accessory cusp expression in extant non-human apes and fossil hominins. The model postulates that the number of enamel knots (and therefore cusps) that can form is determined by the degree of spatial constraints in the tooth germ before the initiation of root formation and mineralization. To test predictions of the PCM, we analyzed three-dimensional models of 276 upper and 487 lower molars at the enamel-dentine junction, which preserves the end point of growth of the inner enamel epithelium. It is also within the inner enamel epithelium that the formation of enamel knots at the dentine horns takes place. All major accessory cusps were analyzed, including the hypocone, cusps 5 and 6 and Carabelli's cusp of the upper molars, and cusps 5, 6 and 7 of the lower molars. By examining the relationship between the proximity of enamel knots and the final crown size of the inner enamel epithelium, we found partial support for the ability of the PCM to explain the range of variation in accessory cusp expression across a taxonomically broad sample of hominoids from the genera *Australopithecus*, *Paranthropus*, *Homo*, *Pan*, *Gorilla* and *Pongo*. The greatest support for the PCM comes from the relationships of these variables in the hypocone and in lower molar cusps 5 and 6. In general, however, our results suggest that molar cusp patterning is more complex than predicted from model organisms and computer modelling.

**Keywords:** accessory cusps, patterning cascade model, enamel knots, enamel, dentine junction, hominoid molars

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# Changing tooth shape and proportions using temporally restricted ectodysplasin treatments

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During tooth development, ectodysplasin (EDA)-signalling is required for normal development of tooth size and shape. In the mouse, lack of EDA-signalling affects several morphological features on all the molars. However, it remains to be determined when EDA-signalling is active during the development of individual teeth and cusp features. Here we dissected the temporal effects of EDA-signalling *in vivo*. Pregnant *Eda*-null mice (mice lacking functional EDA-signaling) and newborn pups were treated with EDA-protein at different time points. The response was studied by analysing the size and cusp patterns of molars using X-ray microtomography. *In situ* hybridization and three-dimensional reconstructions were used to detect the expression of ectodysplasin receptor (*Edar*) in the developing teeth at different stages. We show that each tooth has a specific sensitivity window to EDA-protein, indicating that EDA-signalling is not essential during the full period of molar development. The greatest effects on the tooth phenotype were produced during the initiation of crown morphogenesis when *Edar* is expressed in the primary enamel knot. Smaller effects were detected at later stages when *Edar* is expressed in the future cusp areas containing the secondary enamel knots. Individual treatments altered tooth size proportions, thereby breaking the inhibitory cascade (IC) rule according to which an activator-inhibitor logic determines molar proportions. These results are suggestive of the need for tooth specific regulation in species that depart from the IC predictions.

**Keywords:** ectodysplasin, tooth development, inhibitory cascade, enamel knot, microCT

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# 7. Genetics and epigenetics

# Premolar and molar root morphology in X chromosome aneuploidy

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Premolar and molar root morphology was investigated in 40 females with Turner syndrome (TS) and 40 males with Klinefelter syndrome (KS). Healthy females and males, 80 in each group, served as controls. The aim was to investigate the influence of the X chromosome on dental root development. Root forms were analysed on orthopantomograms and, for the TS, also on periapical radiographs. Premolars were classified as proposed by Midtbo et al (1994). Taurodontism of lower molars was measured according to Shifman & Chanannel (1978). Multi-rooted maxillary and mandibular premolars were found significantly more often in TS group than in all other investigated groups ($p <$ 0.000001). In maxilla there was 2.9% one-rooted, 88.2% two-rooted and 8.8% three-rooted P1 and 28.6% one-rooted, 65.3% two-rooted and 6.1% three-rooted P2. In mandible there was 21.6% one-rooted and 78.4% two-rooted P1, and 51.4% one-rooted, 47.3% two-rooted and 1.4% three-rooted P2 (part of results previously published). There was no difference in premolar root morphology between KS and male controls, or between female and male controls. Lower molars with supernumerary roots were found in 17 TS females (42.5%). Prevalence of taurodontism was 32.1% in KS group (sample size 28), 3.8% in control males ($p < 0.00005$), 2.5% in control females and 3.7% in TS females (sample size 27). The opposite findings in TS and KS indicate that root formation is influenced by the quantity of X chromosome genes with deficiency leading to division of premolar and molar roots, and supernumerary X chromosome leading to late division of molar roots resulting in taurodontism.

**Keywords:** X chromosome, Turner syndrome, Klinefelter syndrome, root morphology

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# Ancient tooth proteomes

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Teeth are a remarkable source of information in paleoanthropological research. Investigation of ancient dental proteomes has the potential to provide complementary biomolecular data such as sex and taxonomic determination, phenotype and disease marker identification, or diet composition, that are essential to understand morphostructural signatures of fossils remains and to get insight on human phylogeny and ancient physiopathology. In the frame of setting up paleoproteomic approaches, human teeth from different archeological periods (present-day to Neolithic) and geographical areas have been analyzed by online nanoflow liquid chromatography coupled to tandem mass spectrometry (nanoLC-MS/MS), using the latest generation of high resolution acquisition speed Orbitrap-based mass spectrometers. After which, the database searches and bioinformatics data analyses have been performed using UniProt or home-made Human protein databases, and dedicated softwares for protein identification. Comparison between samples, tissues and phenotypes will be presented. In addition, in order to identify archaic missense variants with potential impact on modern dental phenotype or pathology, tooth protein non-synonymous polymorphisms known to be associated with dental disorder affecting the integrity of the enamel and those related to enamel thickness, have been searched in the publicly available sequence databases of Neanderthal and Denisova individuals and compared with modern human genome data. The data will bring an overview on the evolutionary relationships between tooth protein polymorphisms and dental structural morphology, with potential impact on the dental phenotype and defect in present-day humans.

**Keywords:** Tooth, Proteomics, Palaeoanthropology, Paleodontology, Polymorphism

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# Missing and extra teeth - the role of the epigenome

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There is growing evidence that developmental tooth anomalies share common genetic influences. Our group has been exploring this using Australian twin cohorts. Phenotypic discordance in monozygous (MZ) co-twins traditionally indicates the influence of the environment. Evidence has been accumulating that epigenetic modifications may also have a role in phenotypic discordance. DNA methylation, one of a range of epigenetic processes, is fundamental for embryological development and has been implicated in disease. The aim of this study was to determine whether differential DNA methylation is associated with differential expression of dental anomalies. The population was sourced from a cohort of Australian twins with available DNA. Phenotypic records included tooth charts of permanent dentition, tooth dimensions and tooth volume. The control group comprised 10 MZ pairs with no agenesis/supernumeraries. The first test group comprised 14 MZ pairs discordant for agenesis. The second test group comprised 6 MZ pairs discordant for supernumerary teeth. Groups were ascertained across a range of tooth sizes. Equal numbers of male and female pairs were selected. DNA samples were subjected to genome-wide methylation analysis using the Illumina450 microarray, interrogating ~485,000 CpG sites. Following routine quality control and data cleaning, we plan to analyse genome-wide and site-specific associations. Despite modest degradation, all samples yielded methylation data. All except one control sample yielded > 425,000 CpG sites. Preliminary analysis of intra-pair correlations for average beta indicated discordance between many MZ twins. There was some evidence that the discordance was greater for twins discordant for dental anomalies. This is the first study to suggest that epigenetic factors may play a role in early dental development. Our preliminary analysis suggests that, genome-wide, there may be an influence of methylation status on tooth embryogenesis. More sophisticated analyses are required for a definitive answer.

**Keywords:** epigenetics, methylation, agenesis, supernumerary, odontogenesis

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# Learning from hairless dogs: the role of the *FOXI3* transcription factor in mammalian dental development

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Hairless dog breeds such as the Chinese Crested, Peruvian Hairless Dogs or Mexican Xoloitzcuintle show a form of ectodermal dysplasia characterised by sparse or absent hair as well as missing and abnormally shaped teeth. This phenotype has been attributed to a heterozygous mutation of the *FOXI3* gene shared by all three breeds. *FOXI3* is a member of the forkhead box transcription factor gene family which is known to have important roles in hair, ear, jaw and dental development. In this study, we investigated the dental phenotype in a 100 year old skeletal collection of pedigreed hairless and coated dogs (n=14). The dental morphology was analysed through microCT-scanning and digital stereo microscopy. Using ancient DNA extraction we identified a heterozygous 7-base-pair duplication in *FOXI3* for all 7 hairless dogs. Unlike in the coated wild type dogs, the hairless dogs were characterised by a loss of the permanent mandibular and maxillary canines and premolars (P2, P3, P4) as well as an altered morphology of the incisors. In addition the haploinsufficiency of *FOXI3* led to an incomplete development of the lingually positioned cusps in the trigon(id) and talon(id) parts of both upper and lower molars and deciduous fourth premolars, respectively. Such a molar phenotype is also found among several living and fossil carnivorans and the extinct order Creodonta in which it is associated with hypercarnivory. Since the molars of great apes and humans also have a variable presence of lingually positioned cusps, we suggest that the *FOXI3* transcription factor may generally be involved in dental cusp formation within and across several mammalian lineages.

**Keywords:** ectodermal dysplasia, cusp development, dental evolution, tribosphenic molar, canids

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# Exploring the genetic architecture of the human diphyodont dental complex: genetic correlation analyses of crown morphology

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Humans are diphyodonts, possessing two successive sets of teeth. While advances in developmental genetics have shed light on the underpinnings of the craniofacial region, this gene-forward approach is limited by its model organism-mice. Rodents possess teeth that are highly derived relative to humans and lack a set of deciduous teeth. Therefore, a quantitative genetic approach is required to explore the link between genome and phenotype for humans. Further, a complete understanding of the architecture underlying the human dentition requires exploration of potential morphological integration among deciduous and permanent crown characters within individuals. We conducted a series of quantitative genetic analyses of deciduous and permanent crown morphology. Data were collected from a pedigreed, longitudinal dental cast sample curated as part of the Australian Twin Study following Arizona State University Dental Anthropology System standards. Heritability and genetic correlation estimates were generated using maximum likelihood variance components analysis in SOLAR v. 8.1.1. Preliminary results from the anterior dentition suggest a high proportion of morphological variance is explained by additive genetic variance. Heritability estimates were higher for permanent characters than for deciduous characters, with the exceptions of shoveling and double-shoveling of the maxillary canine. Results also suggest that the majority of deciduous and permanent homologues share an incomplete pleiotropic relationship. Exceptions include double-shoveling and tuberculum dentale expression of the incisors, which were genetically independent between successive elements. Additionally, distal accessory ridge expression was genetically correlated between deciduous and permanent canines of the mandible but not of the maxilla. These findings point to a complex genetic architecture underlying crown morphology, with varying degrees of integration across dentitions, arcades, and crown surfaces (i.e., labial/lingual). We consider potential developmental explanations for these patterns and discuss the implications of these findings for dental anthropological research.

**Keywords:** dental morphology, quantitative genetics, pleiotropy, dental development, biodistance analysis

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# Quantitative genetic analyses of dental crown morphology: exploring the genetic architecture of anterior tooth traits

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Biological anthropologists use dental crown variation to reconstruct micro- and macro- evolutionary relationships, especially where genetic material is unavailable for study. The reasoning behind this approach is twofold: 1) tooth crowns are highly durable and preserve in most taphonomic environments, and 2) tooth crown characters are thought to be under moderate to strong genetic control. Quantitative genetic studies have confirmed that, for a number of traits, additive genetic variation accounts for a relatively high proportion of dental metric variation. However, few such studies have focused on human morphological characters and their potential pleiotropic relationships. This is unfortunate, as advances in developmental genetics and primate quantitative genetics have shown that aspects of the dentition likely vary and evolve in aggregate. To address this issue, we conducted a series of quantitative genetic analyses of crown morphology, focusing on the anterior dentition. Morphology data were collected from a pedigreed dental cast sample curated as part of the Menegaz-Bock collection; data collection followed Arizona State University Dental Anthropology System standards. Heritability and genetic correlation estimates were generated using maximum likelihood variance components analysis in SOLAR v. 8.1.1. Results reveal that the contribution of additive genetic variation is moderate to high for anterior dental morphology, except for central incisor winging. Shoveling was found to be integrated across the dentition (i.e., across elements, arcades, antimeres), yet tuberculum dentale expression was independent between incisors and canines. Canine traits appear to be genetically independent of one another even within a single tooth, while lingual surface incisor traits are pleiotropic to the exclusion of labial surface features. This suggests shoveling and double shoveling are genetically independent. We discuss these results within a developmental framework and explore their practical implications for biological distance and phylogenetic research.

**Keywords:** dental morphology, quantitative genetics, pleiotropy, dental development, biodistance analysis

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# Genetic and epigenetic influences on teeth, faces and oral health of twins: 35 years of research

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The aim of this presentation is to summarise the main findings of an ongoing study of dento-facial growth and development and oral health in over 1,200 pairs of Australian twins and their families. Three cohorts of twins have been studied using cross-sectional and longitudinal designs and different twin models, including the traditional monozygotic (MZ) versus dizygotic (DZ) twin pair approach, MZ co-twin comparisons and the opposite-sex DZ twin model. Narrow-sense heritability estimates derived from MZ and DZ twin comparisions for dental morphological traits, tooth size, arch dimensions and tooth emergence are generally high, whereas those for facial dimensions, intercuspal distances and occlusal features are lower. Genetic model-fitting methods have disclosed significant non-additive genetic effects and common environmental influences on some dental crown dimensions. There is strong evidence from MZ co-twin comparisons that epigenetic influences are associated with discordance in expression of tooth number between MZ twin pairs. Increased primary and permanent tooth size in females from OSDZ twin pairs compared with females from MZ or same-sex DZ pairs is consistent with the Testosterone Twin Transfer (TTT) hypothesis, suggesting an epigenetic influence of testosterone on dental development. Approximately 20% of MZ twin pairs have been found to be discordant for the timing of colonisation of *Streptococcus mutans*, in terms of whether colonisation occurs before or after the first primary tooth has emerged. This suggests environmental and/or epigenetic in uences on the oral microbiome. 3D imaging and geometric morphometric analyses are now being applied to explore dental shape variability, while molecular techniques and bioinformatics are clarifying the role of the oral microbiome and lifestyle factors on oral health. Further studies of twins and their relatives based on novel technologies should prove to be valuable in the fields of biological anthropology and clinical dentistry during this exciting era of 'omics' and 'personalised medicine'.

**Keywords:** genetics, epigenetics, twins, teeth, oral health

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# X-ray microtomography as a tool for imaging gene expression and tissue morphology in developing tooth

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X-ray microtomography (µCT) imaging is a commonly used technique for morphology studies, allowing acquirement of high resolution 3D data. CT imaging is not limited by tissue transparency and requires no serial sectioning of samples, both issues of which are prevalent in most currently used 3D imaging techniques for visualizing gene expression. Quite recently, µCT imaging has been utilized in combination with silver depositing immunohistochemistry to visualize gene expression at protein level. Here we have developed a 3D method for detecting *Sonic hedgehog* activity in developing mouse molar at mRNA level by combining silver depositing *in situ* hybridization and µCT imaging. Preliminary results imply that for small expression areas like the enamel knot in a developing molar, silver deposition is not enough to create a contrast detectable by laboratory CT. However, we utilized a catalytic gold enhancement method to increase contrast in the sites of expression. This makes the signal detectable by µCT and metal deposition a plausible approach to visualize gene expression in large, opaque tissues. Additionally, the method is compatible with standard phosphotungstic acid staining, enabling visualization of both the morphology of tooth and the gene expression region of interest from an individual sample. Further studies will focus on fine resolution examination of expression regions and mapping the potential in combining the morphological 3D data with gene expression data.

**Keywords:** 3D imaging, X ray microtomography, in situ hybridization, tooth development, *Sonic hedgehog*

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# Oral diseases in historical populations

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Ecological transitions such as changes in lifestyle or diet affect the composition of oral microbiomes. In human history, ecological transitions have promoted the development of dental pathogens, caries and periodontal disease. Recently, metagenomics and "Next generation sequencing" (NGS) have revolutionized the field of paleogenetics by allowing access to ancient genomes and microbiomes. In this approach, tooth represents a relevant substrate as it contains a large quantity of DNA molecules from commensal or pathogenic bacteria present in the oral microbiome. In this context, we studied the oral microbiome of six subjects from a French rural population of the 18th century. These subjects were selected after macroscopic and radiological analysis. We aimed, 1) to identify bacterial communities belonging to the oral microbiome; 2) to specifically identify bacteria responsible for decay and periodontitis; 3) to connect commensal or pathogenic bacteria to pathologies identified macroscopically and radiologically on each subject. First a macroscopic analysis was performed. Infectious signs present on teeth and jaws from six subjects were observed: dental caries, bone loss related to periodontal disease; osteolytic lesions associated with periapical abscesses or residual cysts. Then, six teeth were treated in a dedicated ancient DNA laboratory for metagenomics analysis. The commensal and pathogenic microbial communities were sequenced by shotgun and data analysis was done via MetaphlAn and mapping. Commensal and pathogenic bacterial communities responsible for caries, periodontal and peri-apical infections were identified. *Pseudoramibacter alactolyticus*, *Streptococcus sanguinis*, *Rothia dentocariosa* and *Parvimonas micra* were caracterised. *Streptococcus mutans*, responsible for tooth decay and *Porphyromonas gingivalis*, involved in periodontal disease are abundantly present in these ancient samples. These results are in agreement with the macroscopically observed pathologies as well as with historical data. They also offer for odontologists and anthropologists a view of the oral health status of this rural population of the 18th century.

**Keywords:** Next generation sequencing, ancient microbiomes, oral health status, caries, periodontal disease, periapical disease

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# 8. New methods in dental studies

# Micro-spatial patterning of lead and zinc in deciduous tooth enamel

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The chemical composition of dental tissues can be used to reconstruct aspects of an individual's early life, including nutritional history, residential mobility and exposure to heavy metals. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) or other micro-sampling approaches allow multiple or continuous sampling across the surface of a tooth block or thin section. Such studies have revealed that the distribution of trace elements in enamel is non-homogeneous. This heterogeneity is likely to reflect a range of parameters including environmental exposures and physiology of the individual during the period of enamel formation, the pattern and timing of enamel secretion and maturation, and chemical substitutions within the oral environment. Here, we employ LA-ICP-MS to investigate the distribution of calcium normalised intensities of lead and zinc in enamel from 81 deciduous canines, including 8 sets of paired teeth. Calcium normalised intensities both elements decrease steeply with increasing distance from the enamel surface. Elevated calcium normalised lead intensities are restricted to the immediate subsurface enamel whereas elevated calcium normalised zinc intensities extend further into the enamel. Calcium normalised intensities for both elements are lower than expected in enamel close to a worn enamel surface or close to the cemento-enamel junction. Calcium normalised elemental intensities reach a minimum value in the core region of enamel and then increase slightly towards the enamel dentine junction in some teeth. These distributions indicate that surface enrichment is caused by substitution of lead and zinc into mature enamel through contact with saliva following tooth emergence, and may also be influenced by the accrual of mineral during the maturation phase of enamel formation.

**Keywords:** Enamel, laser ablation, zinc, lead, surface enrichment

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# Imaging cementum in primate deciduous teeth using synchrotron phase contrast micro-tomography

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Cementum is the dental tissue that anchors the tooth to the alveolar bone and grows in-crementally, thus thickening with age. Hypercementosis-overgrowth of cementum mainly at the apical root third-has been observed in Neanderthal teeth especially. Regular cementum formation relates to age while hypercementosis potentially reflects (non-)dietary adaptations. Hypercementosis has been interpreted as an adaptive response to heavy or frequent loads exerted on the anterior teeth in the context of the "teeth-as-tools" hypothesis. The vast majority of previous work has focused on the description of cementum in the permanent dentition. The deciduous dentition has been left unexplored not only because of its temporary nature, but also because these teeth are shed with resorbed roots when the permanent dentition emerges. Here we present a non-destructive imaging of cementum in deciduous teeth of various primates using propagation phase contrast X-ray synchrotron micro-tomography. These juveniles of different dental developmental stages involve Neanderthals, Upper Paleolithic modern humans, chimpanzees, an orangutan, and the Miocene *Anapithecus hernyaki*. Two-dimensional virtual sections in the apical root third of these teeth illustrate the amount and distribution of cementum on the root surfaces. Three-dimensional models highlight the aspect of the root surface, and the accessory root canals running through the hypertrophic cementum in older individuals. Our results suggest this hypercementosis and its expression are linked to a dietary shift occurring after weaning. These non-destructive observations impact our interpretation of the diet and life history of these juveniles in relation with the pattern and timing of their dental development.

**Keywords:** Virtual paleohistology, hypercementosis, deciduous dentition, functional adaptations, root canals

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# Trace elemental distribution in the teeth of male *Papio cynocephalus* clarifies 13C changes related to early dietary transitions

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Laser ablation inductively coupled plasma mass spectrometry (LA ICP-MS) has been used to demonstrate the distribution of trace elements in dental tissues, and assess ages at dietary transitions for human and non-human primates. This study combines such data with δ13C data from the same individual to track dietary changes across baboon development. δ 13C data, and histologically assessed initial formation ages, were obtained for micro-diced enamel samples from a baboon M1, C and M2. Diced samples mixed enamel from as little as 20 days and from at most 5 months. A δ13C profile was made tracking this individual's dietary changes during weaning, and seasonally in later development. Minimum sampling weights, however, for isotope ratio mass spectrometry (IRMS) to analyze δ13C values limited the number of M1 samples to 5. Since baboon weaning takes place mostly during M1 crown formation, more numerous samples were needed from that tooth. LA ICP-MS was then used to obtain Ba/Ca and Sr/Ca values from a second section of the M1 in order to track the timing of weaning-related dietary changes on a finer scale. Laser ablation was conducted at Michigan State University's ICP-MS laboratory. Chromium 2 software was used to analyze levels of barium, strontium, and calcium from a single ablated track of enamel adjacent to the enamel-dentine junction (EDJ). Additional parallel tracks were ablated to show the clearer pattern in the initial one, and to test for consistency. Changes in Ba/Ca moving cervically along the first track increased at birth through the period prior to the first accentuated line, only to decrease after 6 months, while the Sr/Ca values demonstrated the opposite pattern, as did the δ13C values. Combining these datasets and refining LA ICP-MS methods will allow more meaningful interpretations of dietary changes occurring seasonally, across development, and through evolutionary time.

**Keywords:** stable isotope analysis, dental histology, baboon life history, weaning, trace elemental analysis

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# Reconstructing worn cuspal enamel outlines in modern human permanent teeth. A new statistical approach and its application to dental growth studies

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Estimating enamel formation times and enamel extension rates requires the preservation of an unworn crown. Only in unworn teeth can the total perikymata number be counted along the whole crown height and the total thickness of cuspal enamel be measured. However, the methods described in the literature for accurately reconstructing the cuspal outline of slightly worn teeth have not so far been validated. Our aim here is to generate a validated methodology in order to reconstruct the cuspal outline of slightly worn teeth by employing regression equations with defined margins of error. Our sample comprises European and African origin. Standardized microCT slices were obtained for every unworn tooth type. Tooth-specific polynomial regressions were then generated by defining landmarks and semilandmarks superimposed on the unworn outer cuspal enamel outline. A number of tooth cusps were then virtually worn away and subsequently reconstructed by employing the data collected for each specific tooth type using predictions from the regression equations. Estimated crown heights were less than 10% different with regard to their real values in all tooth types. This information allows us to estimate the number of perikymata that might have been lost in the cuspal area more precisely using existing data for density, or perikymata packing, patterns. This methodology allows the reconstruction of cuspal enamel in modern human teeth that are slightly worn enabling the accurate assessment of the original cuspal enamel thickness, crown height and the number of perikymata lost through wear. Future studies aim to increase the robusticity of this method with the inclusion of larger sample sizes. This method can be also potentially applied to other extant or extinct human populations.

**Keywords:** perikymata, reconstruction, regression, enamel, development

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# Sexual dimorphism in primate dental cementum microstructure

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Cementum, the connective tissue connecting mammalian teeth to the periodontal ligament, grows continuously throughout life with an annual rhythm. Growth is recorded by a series of circum-annual increments of contrasting opacity when viewed under light microscopy, with thin hyper-mineralized increments reflecting seasonal reduction in growth rates. The aim of this project is to use high-resolution synchrotron-based radiation tomography (SRCT) to test whether the microstructure of cementum is sexually dimorphic in primates. A sample of macaque lower first molars was taken from the cadavers of animals raised under controlled conditions and with known life histories (raised for an unrelated project and were culled independently). The molar roots were scanned at the Swiss Light Source on the TOMCAT beamline using 40x and 20x objectives at 0.35 and 0.7 µm voxel dimensions (respectively), at 20keV. Reconstructions employed exploratory phase-contrast enhancement ("Paganin-style") algorithms. Reconstructed scans were analysed using novel algorithms, validated and developed in the 'Matlab' statistical environment. Quantitative morphometric techniques were applied to assess variation in microstructure between increments (tortuosity, 3D texture, cellular voids) formed in breeding females, non-breeding females, and males. Analysis of these 3D microstructural data, using principal components analysis and ANOVA comparisons, demonstrates that male cementum increments are relatively uniform and have low microstructural variance, while the increments of breeding females are significantly more tortuous and heterogeneous. We suggest that these characteristics reflect hormonal cycling and the impact of pregnancy. This methodology therefore has potential as a tool for sexing fragmented remains in many other mammalian species, including humans (see the results of Robson Brown et al., also presented at ISDM).

**Keywords:** Cementum, life history, sexual dimorphism, primate, tomography

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# Secondary dentin evaluation using computarized tomography: applicatiion for paleodontology

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Exploring ancient humanoid remains found in prehistoric archeological sites allows significant understanding of many aspects in our ancestor's life. A key question that arises addresses the longevity of these ancestors, and how did key events such as the transition to agriculture effect life spans. We propose the examination of teeth, to unveil the age at death utilizing a novel technique based on inner dentin structure. Current forensic methods use attrition levels for age estimation, yet in an archeological context severe attrition is very common and may not suffice for age assessment. Dentin consists of a primary layer produced during tooth formation and a second layer- secondary dentin (SD) which forms upon tooth eruption and throughout life. The SD layer is preserved even in eroded teeth and has been previously established as a parameter for age by histology, however this method is highly destructive. In the current study we aim to establish non-invasive, direct-virtual analysis of the SD layer based on its radiolucent nature as it appears in micro-computerized tomography (µCT) which will be used for age estimation. Ninety lower second premolars were scanned from the *Hamann-Todd Osteologic Collection* of the Cleveland Museum. Scans were performed using a Skyscan 1178 µCT (Bruker) at a 17.2 micron. Analysis was done using Amira (FEI), reliability was confirmed by comparing histological sections to the virtual scans. An age to SD scale was established while controlling variables of age, tooth type, gender, ethnicity and attrition. Histological comparison to virtual analysis showed high correlation, validating CT analysis. SD was found to be correlative with age and therefore, can be used for an accurate age estimation. Utilizing SD evaluation, we may thus uncover the lifespans of archaic cultures using teeth remnants, which exceed in preservation skeletal remains that are currently used for age estimation.

**Keywords:** Dentin, Micro CT, Age estimation, Imaging, Microevolutionary changes

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# Cementochronology: looking for improving thin section preparation for better results

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Seasonality is an important issue for archaeologists interested by settlement patterns and subsistance behaviours of past populations. There are several ways to assess seasonality but for the past decades, zooarchaeologists have specifically focused on the analysis of seasonal increments in dental cementum of ungulates teeth found in archaeological deposits. Cementum growth is characterized by a predictable annual cycle with the succession of a fast and a slow growth deposit. The identification of the last deposit and its stage of growth is expected to furnish a precise evaluation of the period of death of the concerned individual. Since the late 60's the method has been widely used in order to access to the age at death of fauna and humans, and discuss seasonality of predation in various geographical and chronological contexts. However, for now, the analysis of cementum increments of archaeological teeth relies on the realization of petrographic thin sections, which includes numerous technical steps. While the method has been applied in archaeology for nearly fifty years, there is still no consensus on the sample preparation. We propose to review and evaluate our samples preparation technique by estimating the efficiency rate of each step. The main aims of this work are to improve the protocol of thin section production, to quantify and validate each step and to follow some new lines for future studies on cementum.

**Keywords:** Cementochronology, Thin section, Protocol, Experimentation, Archeology, Cementum increment

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# Tracking dietary changes and mobility patterns at a near weekly scale during childhood by LA-ICP-MS analysis in dental enamel: an experimental study on a Neolithic population in the Paris Basin (France)

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This study presents an experimental analysis by LA-ICP-MS on 62 human and 32 animal teeth from 7 Neolithic sites located in the Yonne valley (Paris Basin, France). Analyses of δ13C, δ15N and δ34S on bone collagen, as well as on dentine were already performed on these samples to trace dietary behaviors. Some distinctions were highlighted between males and females, which led us to inquire if and when the social status could be changed between genders during infancy; and whether such changes could be related to a specific mobility pattern or dietary behavior. Here the teeth were analyzed for Sr/Ca and Ba/Ca elemental ratios as well as 87Sr/86Sr isotopic ratios using Laser Ablation. The second upper molars from humans were selected to track the biochemical signal recorded between ca. 3 and 8 years old. In addition, several animal teeth from different species (from the same sites as humans) were selected to determine the local baseline. The teeth were cut from the top of the mesial crown cusps to the root apex, perpendicularly to the collar, and the LA profiles were drawn in enamel along the enamel-dentine junction (EDJ) in order to cross the transverse striations representative of the entire growth period of the crown. The 87Sr/86Sr ratios as well as Sr/Ca and Ba/Ca ratios were measured along theses profiles using quadrupole and multicollector ICP-MS coupled to the Laser Ablation device. Some measurements were also performed in bone samples from the same individuals to compare the childhood versus adult signals. The profiles show little intra-tooth variations for the overall population and some distinctions between individuals. The method is very promising to provide complementary information about diet and mobility during a well-defined period of human childhood.

**Keywords:** LA ICP MS, strontium isotopes, trace elements, Neolithic, diet, mobility, enamel

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# Estimating ancestry from dental morphology: the development and testing of rASUDAS

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Crown and root trait frequencies compiled from an analysis of the Christy G. Turner II global database were used to develop a web-based application that assigns individuals to a major geographic subdivision of humankind. Observing an individual dentition, 15 crown traits and six root traits are scored as present (at or above a given breakpoint), absent, or unobservable. The analysis generates the probability of an individual being assigned to one or more groups. The method was developed in two stages: (1) Nei's distance matrix was computed treating each crown and root trait as an allelle, from which a hierarchical clustering tree was created using UPGMA algorithm with *complete* linkage. From the tree, seven biogeographic population clusters were defined (Arctic & Northeast Siberia, East Asia, American Indian, Southeast Asia & Polynesia, Austral-Melanesia & Micronesia, Sub-Saharan Africa, Western Eurasia). (2) Probabilistic biogeographic ancestry prediction models were fitted using a *naive Bayes* algorithm that outputs the ancestral group and its associated posterior probability. It is called *naive* because the algorithm assumes total conditional independence between traits. Mathematical conditional independence between variables is assumed, but this is in accord with the working assumption that most non-field crown and root traits are expressed independently of one another. To simplify the usage of this method, a web application named rASUDAS was developed. The application correctly classifies American Indians over 90% of the time while Western Eurasians and Sub-Saharan Africans are classified correctly in over 80% of cases. Southeast Asians, with trait frequencies that are often intermediate on a world scale, are the most difficult to classify accurately. This application has a significant application in forensic science where the estimation of ancestry is a critical part of an individual's biological profile.

**Keywords:** morphology, ancestry, forensics, rASUDAS

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# Simultaneous x-ray excited x-ray fluorescence and x-ray diffraction quantitative mapping of annual bands in cementum using sub-micrometer beams of synchrotron radiation

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Annual bands in cementum have been studied for many years using optical microscopy of thin sections. Results of these analyses (e.g. number of bands and band periodicity) can vary depending on sample preparation, imaging technique and observer subjectivity. The structural and/or chemical changes underlying the light/dark contrast of the bands remain poorly defined: changes in mineral concentration or variation of collagen bril and crystalline mineral preferred orientation may be responsible. This paper reports development of a quantitative and objective approach for measuring cementum band number and periodicity and for determining the microstructure corresponding to the optically-visible band contrast. We use a sub-micrometer diameter synchrotron x-ray beam to simultaneously map x-ray diffraction and x-ray-excited x-ray fluorescence. Polished thin sections (molars, premolars or incisors; modern and archeological specimens) with optically visible cementum bands were removed from their glass slides. Seven reindeer, three human, two bovine and two red deer teeth were scanned using a 250 nm wide, 10.1 keV x-ray beam at station 2-ID-D, Advanced Photon Source (APS, Argonne National Laboratory). The scans extended from air through cementoid and cementum and into dentin at positions where annual bands were visible optically. Significant fluorescence intensities were observed only for Ca, P and Zn, and carbonated hydroxyapatite (cAp) was the only crystalline phase observed in x-ray diffraction patterns. Position-resolved x-ray excited x-ray fluorescence provided orders of magnitude greater sensitivity to trace elements including Zn than electron-excitation methods. Line scans across cementum revealed maxima and minima in Ca, P and Zn fluorescent and in cAp diffracted intensities correspond to band positions in optical micrographs; crystallographic texture in diffraction patterns did not change. We conclude that changes in mineral concentration and not collagen bril orientation produce the optically visible bands. The paper concludes with discussion of the approach's limitations and future research directions.

**Keywords:** cementum, annual bands, synchrotron radiation, x, ray di raction, x, ray fluorescence

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# Application of artificial intelligence in dental age estimation

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Artificial intelligence is intelligence exhibited by computers and machines in terms of ability of a machine to imitate intelligent human behaviour. The term is also used when a computer mimics cognitive functions that humans associate with other human minds, such as "learning" and "problem solving". This is so called known machine learning. There are numerous examples of application of artificial intelligence in daily life like: virtual personal assistants, smart cars, online customer support, news generation, music and movie recommendation services, etc. There are also many applications of artificial intelligence in medicine for diagnostics and therapeutic purposes improving quality of health care and reducing costs and errors related to human fatigue. Dental age estimation can be defined as determination of a person's age or age group from teeth and dental structures. Dental age estimation techniques can be invasive and non-invasive providing more or less reliable results in estimation of age. Skilled and trained experts are required for all techniques. So far there have been no reports of application of artificial intelligence in dental age estimation. The aim of this abstract is to present the preliminary results of a research of an application of a novel dental age estimation technique based on artificial intelligence and machine learning.

**Keywords:** artificial intelligence, dental age estimation

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# A combined dental wear and isotope approach for dietary reconstruction in extant and extinct reptiles with a focus on Crocodilia

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Analyses of microscopic tooth wear were successfully applied for dietary reconstruction of extant and extinct species for over five decades. The most recent semi-automated methods to analyse the 3D surface textures (3DST) allow for repeatable and less observer-biased evaluation of wear patterns on the tooth surface at the nm-scale. These methods were first validated on mammals, which process their food through mastication and are hence ideal for studying the effect of both, mechanical material properties of the food and masticatory movement on dental wear. Many vertebrates, however, do not have specialised heterodont teeth and advanced oral food processing, but mostly rely on a chop-and-swallow strategy, amongst them extant reptiles and fish but also extinct groups such as synapsids and most dinosaurs. In a pilot study we currently transfer 3DST analysis using surface roughness and flatness parameters according to the ISO 25178 and 12871 to extant and extinct reptiles. We here present preliminary data for extinct crocodilians from Messel (Middle Eocene, Germany) and the enigmatic *Iharkutosuchus* (Late Cretaceous, Hungary), which we compare to data from extant squamates and crocodilians from different feeding categories. Surface roughness is greatest in the extinct *Allognatosuchus* (Messel), which is reconstructed as a durophagous species. *Iharkutosuchus* shows lowest surface roughness and extreme flatness, which is similar to extant herbivores from a humid environment. Surface textures in extant reptiles are strongly related to their habitat conditions and proposed dietary categories, thus 3DST of reptiles needs to be carefully interpreted. We will also perform stable isotope analysis (SIA) on the same teeth to assess the diet in a multi-proxy approach, where 3DST provides short-term dietary information, while SIA reflects the long-term dietary signal. By combining 3DST with SIA we expect to better resolve the influence of environmental conditions (e.g. presence of abrasive mineral dust/grit) versus type of diet.

**Keywords:** tooth wear, surface texture, microtexture, reptiles, tribology

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# A "diphyodontic conundrum": do the enamel and dentine of the deciduous and permanent molars tell a similar story?

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Most comparative research on evolutionary primate tooth structure and variation commonly focuses on the elements of one type of dentition, while the extent of covariation in structural organization between deciduous and permanent counterparts remains poorly investigated. We recently used the mandibular second deciduous (dm2) and the first permanent (M1) molars to investigate the degree of covariation in enamel proportions in some extant and fossil hominids. Even if the dm2 and the M1 are not successional elements, they are part of the same developmental molar series sharing a similar and serially repeated structure. Also, compared to the M1, the dm2 is in functional occlusion for a much shorter period of time and it commonly undergoes lower functional constraints. In order to perform intertaxonomic comparisons, by referring to their usual differential use-life, we established a so-called "lateral enamel thickness diphyodontic index" (LETDI) as a measure of the proportions in the amount of non-occlusal enamel. The enamel-dentine junction (EDJ) is the developmental precursor and primary contributor to the morphology of the outer enamel surface (OES) and its shape is recognized as being more conservative of the ancestral morphology compared to the OES. Using recently developed approaches of morphometric mapping and landmarks-based geometric morphometric techniques, we tested some hypotheses regarding the intra- and intertaxonomic variation of enamel and dentine structural signals in dm2-M1 pairs from single individuals sampling the extant hominid genera (*Homo*, *Pan*, *Gorilla* and *Pongo*) and from representatives of four fossil hominid taxa: Neanderthals, *Paranthropus robustus*, *Australopithecus africanus*, *Ouranopithecus macedoniensis*. When considered with respect to a number of biological, behavioural and ecological variables, our results show complex patterns of "diphyodontic signals" suggesting that both deciduous and permanent elements, but also enamel and dentine, hold different and complementary information.

**Keywords:** diphyodontic signal, deciduous second molar, permanent first molar, enamel thickness, enamel, dentine junction

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# Wednesday, 4 October 2017

| Time | Session | Type | Location |
|---|---|---|---|
| 8:00 (1h) | Meeting registration | | |
| 9:00 (30min) | Opening speech | | › Auditorium de l'Agora |
| 9:30 (1h) | 8. New methods in dental studies | Podium | › Auditorium de l'Agora |
| 10:30 (30min) | Coffee break | | › Salle Badiane |
| 11:00 (1h) | 8. New methods in dental studies | Podium | › Auditorium de l'Agora |
| 12:00 (1h15) | 4. Dental function and biomechanics | Podium | › Auditorium de l'Agora |
| 13:15 (1h) | Lunch breack | | › Salle Badiane |
| 14:15 (1h) | 1. Dental evolution in deep time | Podium | › Auditorium de l'Agora |
| 15:15 (2h) | Poster session 2. Teeth and archaeology (humans & animals) & 7. Genetics and epigenetics | | › Cloître |
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| 17:15 (1h) | 1. Dental evolution in deep time | Podium | › Auditorium de l'Agora |
| 18:30 (1h) | Public conference by Jacques Jaubert on Cussac Cave | | › Auditorium de l'Agora |

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| 12:30 (1h30) | Lunch break | | › Salle Badiane |
| 14:00 (1h15) | 2. Teeth and archaeology (humans & animals) | Podium | › Auditorium de l'Agora |
| 15:15 (30min) | Coffee break | | › Salle Badiane |
| 15:45 (1h) | 2. Teeth and archaeology (humans & animals) | Podium | › Auditorium de l'Agora |
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| 10:15 (30min) | Coffee break | | › Salle Badiane |
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| 14:45 (1h) | 5. Odontology and paleodontology | Podium | › Auditorium de l'Agora |
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| 16:15 (1h) | 7. Genetics and epigenetics | Podium | › Auditorium de l'Agora |
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| 20:00 (3h55) | Closing diner | | |

Legend: Podium session — Poster session — Speech — Break