Proceedings of the 15th International Symposium on Dental Morphology, Newcastle upon Tyne, UK, 2011

Abstracts of the 15th International Symposium on Dental Morphology

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Wendy Dirks

ALPHABETICAL ORDER*

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The interactive London atlas of tooth development and eruption

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The aim of this study is to present an interactive computer programme of the London Atlas of tooth development and eruption. The sample was made up of tooth formation and eruption state of all teeth from 72 prenatal and 104 postnatal skeletal remains of known age-at-death and the Royal College of Surgeons of England and the Natural History Museum, London, UK. Data were also collected from dental radiographs of living individuals (264 males, 264 females). Median stage for tooth development (after Moorrees et al.1963) and eruption relative to the alveolar bone was recorded and are illustrated. The programme comprises of three sections. 1. Playback mode is an overview of dental development between 28 weeks in-utero and 23 years. 2. Data entry mode is an electronic age estimation calculator with data entry mode. 3. Comparison mode for dental development amongst sexes of the same age or the same sex in different ages. This programme provides practical information suitable for researchers, students and specialists to enhance age estimation skills based on dental formation and also provide better understanding of tooth development.

3D geometric morphometrics tooth shape analysis in hypodontia

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Accurate quantification of variation in tooth shape is important in hypodontia patients. Several techniques have been used to quantify tooth size and shape in hypodontia patients and these have shown smaller tooth dimensions and anomalous tooth shapes in these patients when compared with controls. However, previous studies have mainly used 2D images and provided limited information. In the present study, 3D surface-imaging and statistical shape analysis were used to evaluate tooth form differences between hypodontia and control patients. Eighteen anatomical landmarks were recorded on the clinical crown of the lower left first permanent molar of 3D scanned study models of hypodontia and control subjects. The study sample comprised 120 hypodontia patients (40 mild, 40 moderate and 40 severe hypodontia patients) and 40 age- and sex-matched controls. Procrustes coordinates were utilized to scale and superimpose the landmark coordinate data and then were subjected to principal component analysis (PCA). Subsequently, shape differences were tested statistically using MANOVA. Significant interaction was found between the two factor variables “group” and “gender” ($p < 0.002$). Overall expected accuracies were 66% and 56% for females and males respectively in the discriminant analysis using the first 20 PCs. There appears to be progression in shape variation from mild, to moderate to severe hypodontia, while the controls are isolated from all three groups. Hypodontia groups showed significant shape differences compared with the control subjects ($p<0.0001$). Significant differences in tooth crown shape were also found between sexes ($p<0.0001$). The degree of variation in tooth shape was associated with the degree of the severity of the hypodontia. Quantitative measurement of the tooth shape in hypodontia patients may enhance the multidisciplinary management of those patients.

The intersection of experiment and theory: using cutting tests and FEA models to understand how teeth fracture food

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Material properties of food items can exert a strong influence on tooth morphology. Previous experimental studies have shown that the morphology of bladed dental tools can have a significant effect on the energy required to cut various biological tissues. We integrate further experimental analyses with theoretical finite element (FE) modeling to explore the relationship between blade shape and food materials. Our aim is to create a strong link between experimental and theoretical data to better understand dental functional morphology. We used a double guillotine testing device to cut various biological tissues (fish muscle and plant materials) and standardized homogenous materials (photoelastic resin). We measured work to fracture during cutting using tool shapes based on dental morphology. We built FE models that matched the guillotine structure: a test material given properties of the resin compressed between rigid features shaped like cutting tools. Stress and strain and reaction forces were calculated for a variety of dental tool shapes. Experimental results confirm previous analyses which show that the effects of dental shape are dependent on the physical properties of the materials being cut. FE analyses based on photoelastic resin replicate both strain patterns and force values produced by the experiments, allowing us to read the stress and strain values calculated as real. The FE analyses show distinct differences in both the levels and patterns of strain present in test materials cut by different tool shapes. These results show the power of integrating experimental data and theoretical models to approach biomechanical questions.

Proceedings of the 15th International Symposium on Dental Morphology, Newcastle upon Tyne, UK, 2011

Metric and morphological analysis of *Cantius* molars from the Great Divide Basin, Eocene of Southwestern Wyoming

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Fieldwork over the past 15 years in Eocene deposits of the Wasatch Formation in southwestern Wyoming has yielded over 10,000 fossil mammals from nearly 100 localities spanning the Paleocene-Eocene boundary. One of the most commonly represented taxa in this sample is the adapid primate *Cantius*, approximately 500 specimens of which have been found at 47 localities in our field area spanning much of the early Eocene Wasatchian North American Land Mammal Age (NALMA). Species of *Cantius* from the Bighorn Basin have played a significant role in most attempts at biostratigraphic zonation of the early Eocene. However, large samples of *Cantius* from other sedimentary basins in the Rocky Mountain West have rarely been described and compared in a biostratigraphic context to the Bighorn Basin sample. In this poster we present descriptions and dental metrics for the entire Great Divide Basin sample of *Cantius* molars and compare the results to the Bighorn Basin evolutionary and morphological sequence. Changes in molar size, development of cinguli, conules and hypocones reflect evolutionary change within several lineages of *Cantius*. Differences between the evolutionary sequences in northern (Bighorn Basin) and southern (Great Divide Basin) Wyoming may reflect migrations between sedimentary basins and range extensions in response to early Cenozoic climatic changes.

Differentiating the indifferent within the human dentition: what should we look for?

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Teeth are used by forensic odontologists to correctly identify a person through comparison of features. The presence of restorative work and dental features such as tooth anomalies will often contribute to positive identification. Prevalence of a number of dental features (Carabelli trait, incisor shoveling, etc.) may also be considered population-specific. These features can greatly assist in profiling the ancestry or geographical origin of a person. The study of tooth variation has greatly increased our knowledge and understanding of this area. We are seeking to extend the range of useful comparators. Using 2D and 3D approaches, we have developed standardization protocols required to incorporate metric measurements of dental features such as mesiodistal (MD) and buccolingual (BL) crown diameters and interarch widths. Here, we present our findings of comparisons of upper and lower teeth in pairs of identical twins of European ancestry and in other population groups, including Malaysians and Australian Aboriginals. The presence of a scale in 2D images is especially important. Different scanner settings may also affect the end result of the scanned object. These settings include *laser gain, stripe threshold, X-range limit and Z range cutoff.* Problems and issues that need to be overcome to ensure optimal outcomes have been evaluated. This has helped in identifying which metric measurements of these dental features are most suitable statistically for differentiating one person from another. We propose to combine multiple dental traits and use multivariate models to achieve better outcomes in human identification using the dentition.

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Proceedings of the 15th International Symposium on Dental Morphology, Newcastle upon Tyne, UK, 2011

What does it mean to be (dentally) "modern"?

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In the past decade much research has focused on identifying dental characters that distinguish *H. neanderthalensis* from anatomically modern *H. sapiens*. Some of these characters (or combinations thereof) have been hypothesized to be derived for *H. neanderthalensis* and their lineage, while others are likely primitive. The dentitions of some recent *H. sapiens* populations have been characterized as primitive (e.g., Sub Saharan Africans), while others have been characterized as derived relative to other populations (e.g., Northeast Asians). However, to date no study has proposed a dental pattern that characterizes *H. sapiens* as a species. This study addresses two questions (1) whether or not there is a suite of dental characters that is derived for *H. sapiens*; and 2) if so, when during the course of human evolution this pattern emerged. Size notwithstanding, *H. sapiens* possesses few derived dental traits that distinguish them from earlier hominins. In addition to the large occlusal polygon of the lower P3 identified by Gomez-Robles et al. (1), these traits include a U-shaped fissure pattern of the lower P4, relatively flat, featureless upper incisors that are buccolingually narrow, and lower molars that lack a hypoconulid and any form of trigonid crest. Early *H. sapiens* from Qafzeh, Klaises River Mouth and Jabel Irhoud possess some of these characters. Interestingly, none of the recently discovered teeth from Qesem Cave, Israel exhibit any derived *H. sapiens* non-metric traits; while the molars of *H. floresiensis* are derived toward the *H. sapiens* condition.

(1) Gómez-Robles A, Martinón-Torres M, Bermúdez de Castro JM, Prado L, Sarmiento S, Arsuaga JL. Geometric morphometric analysis of the crown morphology of the lower first premolar of hominins, with special attention to Pleistocene *Homo*. J Hum Evol. 2008;55(4):627-638.

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Combining 3D Finite Element Method and Occlusal Fingerprint Analysis

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Occlusal load simulations based on finite element analysis (FEA) are usually employed to evaluate the stress and strain distribution in teeth or dentures. However, FEA is normally adopted without considering changes in occlusal contacts between antagonistic teeth during the power stroke. In this contribution we show how individual occlusal information, i.e. the kinematics of antagonistic teeth, can be used to investigate the stress distribution with FEA in M1.

The M1 and the P4–M1 of three dried modern human skulls were scanned by µCT in maximum intercuspation contact. A kinematic analysis of the surface contacts during the power stroke between M1 and P4–M1 was carried out in the Occlusal Fingerprint Analyser (OFA) software, and contact areas per time-step were visualized. Stress distribution in the M1 during phase I, maximum intercuspation and phase II stages were analyzed in Strand7 FEA software, considering the occlusal information taken from OFA results for individual loading direction and loading area.

Our FEA results show that the stress pattern changes during the power stroke, suggesting that wear facets act to distribute the stress into the crown. Grooves and fissures in the occlusal surface are seen as critical locations, as tensile stresses are concentrated at these features. Properly accounting for the power stroke kinematics of occluding teeth result in significant reduction in tensile stresses in the crown of the tooth. This leads to the conclusion that functional studies considering kinematics of teeth are important to understand biomechanics and interpret morphological adaptation of teeth.

Proceedings of the 15th International Symposium on Dental Morphology, Newcastle upon Tyne, UK, 2011

Permanent tooth development in bonobos (*Pan paniscus*) and chimpanzees (*Pan troglodytes*)

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Although life history does not fossilize, it may be reconstructed by comparing the dental development of extinct hominins with that of their closest living relatives. Thus far, modern humans and chimpanzees have been the two chief comparison species. To accurately infer life history from fossil dental remains requires an understanding of the normal range of variation in human and African ape dental developmental sequences and timings. Despite that chimpanzees and bonobos are sister species and both are the closest living cousins of modern humans, bonobo tooth formation and eruption has been virtually undescribed. This study aims to fill this significant gap in what is known about dental development in *Pan*. Here we compare relative stages and times of permanent tooth crown initiation, crown completion, root extension and tooth eruption between 44 *Pan paniscus* and 58 *Pan troglodytes* mandibles radiographed in lateral and occlusal views. In bonobos, P3 crown mineralization starts slightly earlier relative to P4 initiation compared to chimpanzees. Also in bonobos, both premolar crowns have fully mineralized earlier relative to M2 crown completion and M3 initiation than in chimpanzees. While there is about 6 months of overlap between M1 crown completion and M2 initiation in chimpanzees, there is about a third or less of this overlap in bonobos. Lastly, compared to chimpanzees, we found about the same period of overlap between M2 crown completion and M3 crown initiation. Data for eruption and anterior tooth development will also be presented here.

Proceedings of the 15th International Symposium on Dental Morphology, Newcastle upon Tyne, UK, 2011

Immunodetection of Smad4 during molar root formation in alendronate-treated rats

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During root formation, Smad4 plays a key role during the epithelial-mesenchymal interactions that induce the apical proliferation of Hertwig's epithelial root sheath (HERS). Alendronate (ALN) treatment of young rats suppresses bone remodeling, which causes ankylosis and the arrest of eruption and molar root formation. The present study aimed to immunodetect Smad4 into the structures affected during molar root development in rats treated with ALN. Newborn Wistar rats daily received 2.5mg/kg ALN; the controls (CON) were injected with saline. At 7, 9, 12 and 30 days, the maxillae were fixed in 0.1% glutaraldehyde + 4% formaldehyde and embedded in Paraplast or Spurr resin. Paraffin sections were incubated with a Smad4 antibody and revealed with DAB. Ultrathin sections were examined in a JEOL 1010 TEM. In ALN, only a short portion of root dentine was formed, while the epithelial diaphragm (ED) and the dental follicle (DF) were severely disorganized by the contact of bone trabeculae; the CON molar roots developed normally. While in ALN group few DF cells presented weak Smad4 labeling, in CON it was detected in the cytoplasm of fibroblasts and cementoblasts adjacent to the cementum. Ultrastructurally, both ED and DF appeared disrupted due to the presence of thin bone trabeculae between their cells, which resulted in the absence of HERS, and therefore in the arrested root formation. The immunodetection of Smad4 in DF cells of ALN specimens suggests that signaling for cell differentiation occurs, despite the impairment of root elongation. Grants # 06/60094-5 and 09/54853-9 (Fapesp, Brazil).

Incremental markings in fluorotic porcine enamel

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Using light and scanning electron microscopy (both secondary electron and backscattered electron imaging), we studied incremental markings in fluorotic enamel of mandibular third molars of (a) Hanford miniature pigs fed a daily oral dose of 2 mg sodium fluoride per kilogram body weight over one year and (b) free-living wild boars from a fluoride-polluted area of Central Europe killed during normal hunting operations. The fluorotic enamel was particularly suited for recording incremental markings, since their visibility was higher than in normal enamel. Incremental markings with different periodicities could be distinguished. The spacing of the long-period incremental markings increased from about 8 µm near the enamel-dentin junction to about 25 µm in outer enamel. In axiobuccolingually orientated ground sections through the cusp tips of the central lobe, around 230 of these lines, denoting the respective position of the surface of the forming enamel, were observed in appositional and imbricational enamel. Between successive long-period markings, five to six short period markings (prism cross striations) were recorded. In the light microscope, the latter appeared as alternating light and dark striations orientated perpendicular to long axis of the prisms. In the scanning electron microscope, alternating constrictions and varicosities were observed along the prism long axis. In addition to the cross striations, we observed further markings in the form of very fine striations in both enamel prisms and interprismatic enamel. The repeat interval of the different incremental markings observable in porcine enamel remains to be established.

Proceedings of the 15th International Symposium on Dental Morphology, Newcastle upon Tyne, UK, 2011

Fruit proportion and consumption of hard items in the diets of primates correlate with 3D microwear textures

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The 3D dental microwear texture analysis is useful in reconstructing the diets of extinct primates. This method is based on the comparison of fossils with extant species with known diets. The diets of primates are very diversified and include fruits, seeds, grass, tree leaves, bark, roots, tubers, and animal resources. Fruits remain the main component in the diets of most primates. We tested whether the proportion of fruits consumed can be significantly correlated with microtexture. Two microwear texture methods, the scale-sensitive fractal analysis (SSFA) and the ISO/FDIS 25178 texture analysis (ISO), are applied on eight primate species (*Alouatta seniculus, Gorilla gorilla*, *Lophocebus albigena, Macaca fascicularis, Pan troglodytes, Papio cynocephalus, Pongo abelii, Theropithecus gelada*). These species largely differ in their mean annual fruit proportions (from 0 to 90%) in their diet, as well as in their consumption of other hard items (seeds, bark, and grass). The complexity and heterogeneity (SSFA) of textures correlate with the proportion of fruits consumed. The textural fill volume (SSFA) indicates the proportion of hard items processed. Last, the anisotropy (SSFA) relates to the consumption of grass. On the other hand, the ISO parameters (valley height, root mean square height, material volume, density of peaks, and closed hill and dale areas) describe the functional interaction between food items and enamel facets during mastication: attrition as induced by tough and soft foods vs. abrasion as induced by local enamel fracturing caused by hard items.

Difference in development of the supernumerary cheek tooth in Sprouty mutant mice

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Sprouty 2 mutant (Spry2-/-) mice show a supernumerary tooth in their mandibular cheek dentition. This tooth is situated anteriorly of the first molar (M1), where a tooth-less diastema is present in wild type (WT) mice. Origin of the supernumerary tooth involves the revitalization based on morphogenetic mechanisms in the rudimentary diastemal tooth bud (called R2). Indeed, in early development (at embryonic day ED13.5), the R2 rudiment shows increase of proliferation and decrease of apoptosis in Spry2-/- embryos. However, one more rudimentary primordium (called MS) rises in the prospective diastema region. We aimed to get information about the participation of both the anterior (MS) and posterior (R2) rudimentary tooth primordia in the development of the supernumerary tooth. We compared the proliferation, apoptosis and size of dental epithelium in the MS and R2 rudimentary bud, and analyzed their development in different genotypes of Sprouty mice that all exhibit a supernumerary tooth formation: Spry 2-/-, Spry4-/-; Spry4-/- or Spry2+/-; Spry 4-/- mice at ED12.5 – 13.5. We made 3D reconstructions, counted proliferation index, apoptotic rate, and measured the area of dental epithelium on histological sections. In comparison to WT embryos, all Sprouty mutant mice generally exhibited an increase of proliferation and decrease of apoptosis in the rudiments. However, there was a different time schedule of these events in particular genotypes. We propose that the different timing is related to variability in supernumerary tooth morphogenesis.

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Dental morphology at the ancient site of Alalakh

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The site at Alalakh, located on modern-day Tell Atchana in Hatay Province, Turkey (36◦ 14'15.71" N, 36◦ 23'03.86" E), contains a Bronze Age cemetery where dental anthropology can inform archaeologists about ancient populations. Located between the Mitanni, Hittite, Assyrian, and Egyptian Empires during the Middle and Late Bronze Ages (2000-1200 B.C), Alalakh was strategically positioned for both commerce and regional governance and underwent several periods of administrative change. Problematic ambiguities remain since historical documentation illuminates the major events but not the lives of common people, while bioarchaeologists are confounded by taphonomic conditions at the site. The issue investigated here is whether these bureaucratic and commercial shifts can be equated with demographic or biological change seen in the dentition of the people of Alalakh. Materials used include craniofacial fragments, and loose teeth (N = 408) from approximately 60 individuals. Odontometric techniques and non-metric dental assessments are applied to elucidate the relationship between diet, age, sex, and phenotype. These techniques create a more nuanced and specific biological profile of the people of Alalakh, and underscore differences within that population. Initial non-metric assessments show evidence of caries and hypoplasia, while age at death varies widely. Preliminary odontometric analysis indicates that size variation occurs through time, but also among individuals in the same time periods. This research is discussed in connection with ongoing efforts to establish a realistic and representative bioarchaeological profile of Alalakh. More broadly, it contributes to our understanding of ancient Near Eastern populations and the importance of dental anthropology in archaeological investigation.

Fractures in teeth provide information on bite force and tooth function.

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Tooth enamel is brittle and highly susceptible to cracking. We propose that observations of such cracking can be used as a diagnostic tool for predicting bite force and inferring tooth function in living and fossil mammals. Laboratory tests on model tooth structures and extracted human teeth in simulated biting identify the principal fracture modes in enamel. Examination of museum specimens reveals the presence of similar fractures in a wide range of vertebrates, suggesting that cracks extended during ingestion or mastication. The use of fracture mechanics theory from materials engineering provides elegant relations for quantifying critical bite forces in terms of characteristic tooth size and enamel thickness. The role of enamel microstructure in determining how cracks initiate and propagate within the enamel (and beyond) is also explored. The picture emerges of teeth as damage tolerant structures, full of internal weaknesses and defects and yet able to contain the expansion of seemingly precarious cracks and fissures within the enamel shell. Such an understanding of 'dental fracture mechanics' can aid in the dietary reconstructions of extinct taxa.

Patterns in the origin of multicuspid teeth among terrestrial amniotes

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The origin of multicupsid teeth is frequently held to be a key evolutionary innovation, especially of mammals. However, multicuspid teeth have independently been acquired by a number of vertebrate clades. Here we concentrate on terrestrial amniotes to examine morphological, developmental and ecological patterns shared across these independent origins. Examining taxa in a phylogenetic and chronological context, we first analysed the Procolophonoidea, a Permian and Triassic (255 to 200 MA) radiation of small reptile-like animals within the wholly extinct clade Parareptilia, which putatively were the earliest amniotes to develop 'true' multicuspid dentitions. All Permian taxa had numerous, identical conical teeth, but Triassic species evolved a wide diversity of heterodont and/or multicuspid dentitions. We micro-CT scanned lower and upper jaws of the Triassic procolophonid *Kapes bentoni.* Tomographic models of the internal structure of the teeth show an Enamel Dentine Junction (EDJ) and pulp cavity which mirror the shape of the bicuspid molar teeth; we hence consider the teeth of *Kapes* to represent true multicuspid teeth. We then analysed phylogentically and chronologically early members of multicuspid radiations within Synapsida and Diapsida, the other two branches (with Parareptilia) of Amniota, including notosuchian crocodiles, basal pterosaurs, basal archosauromorphs, basal lepidosaurs and basal therapsids. Despite the disparate taxa, key features of each of these radiations are the relatively similar mode of multicuspal origin, and the relatively small body size of the first multicuspid taxa. These results indicate that both developmental and energetic factors may have instigated the stereotypic origins of multicuspid teeth.

Rates of dentine formation and root extension in *Dryopithecus* and *Pan* compared

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Three previously described molar teeth attributed to *Dryopithecus laietanus* were reanalysed with a particular view to determining rates of dentine formation and root extension, and comparing these with new data for *Pan troglodytes*. Increments of daily root dentine formation close to the granular layer of Tomes (GLT) were imaged in IPS-1781 (M^1) and the gradient of increasing rates recorded in zones of 100µm deep to the GLT. The average rate of ~20 measurements per 100µm zone rose from ~2.0 to 2.5µm/day over 200µm deep to the GLT. These were similar to rates measured in *P. troglodytes* where between 80 and 90 daily increments could occasionally be counted directly within this 200µm zone. These average daily rates were used to reconstruct rates of root extension along the cement-dentine junction (CDJ) from the enamel cervix apically. Root extension rates in *Dryopithecus* rose from 4.1µm per day at the cervix to a maximum of 8.9µm per day at 4828µm root length (equivalent to 4.27 years of M^1 formation) and then fell back to 5.1µm per day at 8000µm. The timing of the peak in root extension rate falls within the range observed in 14 *P. troglodytes* M1s and this in turn corresponds closely with the range of gingival eruption ages documented for captive and free-living *Pan.* These new data suggest that rates of root extension, even in isolated teeth, may contribute to the ongoing debate about gingival emergence times in living and fossil primates.

Subspecific variation in the skulls of baboon and vervet monkeys: Assessing the dietary signal

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Both the vervet, *Chlorocebus aethiops*, and the baboon, *Papio hamadryas*, are notable among the Old World monkeys for the considerable span of their geographic ranges and the presence of regional subspecific forms. The two monkeys occupy most of sub-Saharan Africa and are broadly generalist and adaptable. However, there is evidence for dietary differentiation between populations. This study seeks to visualise and quantify the correlation between diet and skull morphology within the two monkeys. It also aims to determine if this pattern is explicable in terms of adaptations in masticatory biomechanics to food physical properties such as toughness and hardness. Comparison of the two patterns of intraspecific diversity will reveal if these separate evolutionary radiations show a similar response to diet indicative of convergent evolution or not.

To correlate diet and morphology 2-block partial least squares is used. The dietary block comprised proportions of food categories consumed, derived from the primatological literature. The morphology block was 3D skull landmark data from museum specimens. Lever arm mechanics was used to calculate the mechanical advantage of muscle vectors corresponding to the temporalis and masseter to give a measure of functionality.

The partial least squares analysis reveals significant associations between diet and morphology within the two species. Visualisations of these morphologies are presented. Mechanical advantages appears unrelated to diet and is correlated with size, perhaps suggesting changes in muscle area rather than orientation are the primary adaptations to consuming foods of variable properties. The similarity of the baboon and vervets subspecific variation is discussed.

Research in, research out: the development of a searchable, web-based case file of orthodontic records

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In 2005, The Maxwell Museum of Anthropology received an important donation from a local orthodontist, a case file that includes dental models, patient records, and over 400,000 images (photographs and radiographs) of 5,650 individuals taken before and after treatment. The collection represents the ethnic diversity of Albuquerque, New Mexico from 1972 to 1999, including African, Asian, European, Hispanic, and Native Americans. All subjects were treated orthodontically, but there is a considerable range of ages, from childhood, many adolescents, and adults. Most cases are phenotypically normal, but there are some records of clefts and other syndromes. A number of challenges attended the donation, including storing, funding, and developing a process for making the collection available for research. Additional issues related to patient privacy, estimating the ancestry of individuals in the collection, creating a standardized terminology for cephalometrics and other data, and creating a user-friendly web-based interface for the de-identified portion of the collection's database.

This paper describes the research components of developing a new resource for general use, concentrating on standardizing terms for cephalometric measures and providing reliable information about patients' race and ethnicity. Additionally, results of a study comparing intra-individual deciduous and permanent tooth dimensions in European American females will be described, providing an example of the myriad projects possible with this collection and case file. Images and patient records in the J.K. Economides orthodontic patient record collection are now on line and freely available for research and education (http://hsc.unm.edu/programs/ocfs).

Patterns and constraints in carnivoran and rodent dental complexity and inhibitory cascade models

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It has been known for centuries that general tooth shape correlates with diet in mammals. Our previous work quantified one aspect of this relationship, showing that the 3D complexity of cheek tooth rows is a robust measure of broad diet in carnivorans and rodents quantified as orientation patch count (OPC). Here, we extend this to investigate patterns of dental complexity of individual teeth along a tooth row.

Within the rodents, there is a consistent pattern of decreasing OPC from anterior to posterior along the tooth row for all of the diet categories. However, the more herbivorous the diet is, the greater the OPC for each single tooth. The story is quite different for the carnivorans, where there is much more diversity in terms of variation within a tooth row and differences in patterns between the diets.

Therefore, rodent dentitions appear more constrained, not just in the number of teeth in a row but also in variation of dental complexity along the row. This corresponds with the constraint in relative tooth sizes along the row, as illustrated by the inhibitory cascade model. The carnivorans show some deviation from the strict inhibitory cascade rule, with most of the species falling some distance from the line. However, there is a relationship between the strength of the inhibitory cascade and the dental complexity. We suggest that changes in tooth proportions (through the inhibitory cascade) are incidental with respect to ecology, and reflect the way dental complexity changes in response to evolving dietary preferences.

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Enamel thickness in Asian human canines and premolars

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Enamel thickness features prominently in studies of ape and human evolution. Little is known about the degree of enamel thickness variation among human populations, particularly across the dentition. Recent applications of microtomography allow scientists to employ larger and more diverse samples, including recent and fossil hominin teeth. Microtomography was employed to virtually image, section and quantify the average enamel thickness of clinically extracted Indonesian canine and premolar teeth. This virtual sample was compared to physically sectioned African and European teeth. The results demonstrate that average enamel thickness is similar among human dentitions; no significant differences were detected within tooth positions, which is surprising given developmental differences between European and African canines and premolars. When populations were combined, differences were found in average enamel thickness between maxillary and mandibular premolars, and between canines and premolars within both arcades. This may be due to differences in premolar morphology and a trend of increasing enamel thickness distally throughout the dentition. Limited population variation within tooth positions and significant variation between tooth positions is consistent with previous two- and three-dimensional studies of human molar enamel thickness. Average enamel thickness in canines and premolars does not differ between the sexes in our sample, although males tend to have larger enamel and dentine cross-sectional areas, enamel-dentine junction lengths, and bi-cervical diameters. Males also showed significantly greater dentine area and enamel-dentine junction length for maxillary canines and premolars. These results suggest that enamel thickness values in mixed-populations of humans are appropriate for comparisons with fossil hominins. Supported by the Max Planck Society and Harvard University.

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An allometric approach to the growth of the hard palate in *Pan troglodytes* and *Macaca fuscata*

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Apart from the possible biomechanical function of the mammalian hard palate for strengthening the rostrum, growth and development of the palate depend on numerous factors such as genetics, dentition, tongue pressure, and breathing. In order to explore the variation in palatal form among different primates, the postnatal growth of the hard palate of a cross-sectional series of dry crania of *Pan troglodytes* (N = 52) of different postnatal ages was compared with a cross-sectional series of skulls of the Japanese macaque (N = 30). Coronal CT scan series served to characterize the palatal form. The contours of the hard palate were digitized and the palatal volumes (PV) were calculated using the WinSurf® Software (developed by Scott Lozanoff). Reduced major axis analysis indicates a common growth pattern of male and female primates of both species. The comparison of the regression slopes of the pooled sexes indicates that the PV of the chimpanzee enlarges postnatally faster than in the Japanese macaque. This suggests that the palate of a given primate species enlarges according to its own growth pattern. Differences in palatal form between primate species may be due in part to differences in the postnatal growth pattern. Since the palate is essentially part of the midfacial skeleton, it is likely that these variations in growth pattern of the hard palate may have implications for the association between the hard palate and other components of the midfacial skeleton as well.

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Estimation of the developmental stability of the mediaeval population from Gródek on the base of a presence of enamel hypoplasia and the fluctuating asymmetry.

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Enamel hypoplasia, cribria orbitalia, Harris's lines and in the last years the fluctuating asymmetry are the most common indexes of the developmental stress. These features allow an approximate reconstruction of the economic and health status of the studied populations. The aim of the study was the assessment of the disorders of homeostasis of the medieval population, expressed by the presence of enamel hypoplasia and fluctuating asymmetry and the estimation of the relationship between these two determinants of physiological stress.

The material consists of 70 skulls from the medieval population of the Gródek township on the river Bug. Developmental Defects of Enamel Index (DDE) was used to assess hypoplasia.

Measurements of the characteristics bilateral points were performed on radiographs of the skulls(basal and the P-A projections). Directional and fluctuating asymmetry were assessed in the examined sample. In order to determine the magnitude of FA, three different computational methods were used according to Hershkovitz et al.(1990; 1992; 1993), Palmer and Strobeck, (1986) and Van Valen (1962). The statistical analysis was performed. The skulls showed the presence of the fluctuating asymmetry. The highest level of fluctuating asymmetry was observed in the region of skull's base. Dental enamel hypoplasia was observed in an examined sample. We found close correlations between the presence of the fluctuating asymmetry and enamel hypoplasia in the studied group.

The continuous dental replacement in mammals: new insights from the discovery of a new case in the silvery mole-rat, *Heliophobius argenteocinereus* (Bathyergidae, Rodentia)

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While mammals usually develop two generations of teeth vertically replaced, the three manatee species and one wallaby, the nabarlek, display amazing innovations consisting in having molars continuously replaced. Such continuous dental replacement (CDR) is not vertical as in their ancestors (i.e. mammal-like reptiles), but horizontal, and it is assumed to be an adaptation to withstand highly abrasive and tough food intakes. Here we report a new discovery in an African bathyergid rodent, *Heliophobius*, which sheds new light on this poorly known phenomenon. This rodent presents the particularity to combine the CDR with high crowned teeth that constitutes an adaptation to hyper chisel-tooth digging involving a high amount of exogenous dust ingested, implying thus intense dental wear. The differences from the manatees and the nabarlek also rely on its single-rooted and high crowned molars, and on its slightly different model of dental replacement and resorption. Although this CDR has been acquired independently in phylogenetically distant mammals, we found that frequently inherited biological traits, such as supernumerary molars, dental mesial drift, and delayed dental eruption can constitute essential prerequisites for the setting up of CDR. Bathyergid rodents are known to be of great interest for topical issues such as cancer resistance, extreme longevity or evolution of highly cooperative breeding system in mammals (in genera *Heterocephalus* and *Fukomys*). Here, they represent crucial models for the prospective understanding of CDR in mammals, the molecular processes involved and its further application in human dentistry.

The variation of molar occlusal morphology in subjects with 46,Xi(Xq) chromosome constitution

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Previous studies have shown that Turner syndrome has an influence on size, shape, and structure of teeth. The aim of this study was to analyse the molar occlusal morphology in Turner patients with 46,Xi(Xq) chromosome constitution and compare them to a control group of healthy relatives. Furthermore the study was done to find out if individuals with 46,Xi(Xq) chromosome constitution have an increased asymmetry in occlusal components between corresponding teeth on the right and the left side.

The subjects were six Finnish females with 46,Xi(Xq) chromosome constitution and controls seven first-degree relatives of the 46,Xi(Xq) patients. The material is a part of Kvantti dental reseach project on subjects with sex chromosome aberrations. The linear and angular variables of the upper and lower permanent first and second molars were measured on the 3D-images taken of the dental casts of the participants. Images were created by using Orthometrics, a special computer program connected to a camera.

The group of 46,Xi(Xq) patients presented reduced size of teeth. Also increased asymmetry, both directional and fluctuating type, was found. The differences between patients and controls appeared most often in the second mandibular molars, being statistically significant ($p < 0.05$).

Our findings agree with the previous studies which have suggested that both X chromosomes are active in amelogenesis and promote enamel apposition. If size, shape or structure of teeth is altered, it may depend on the structural abnormality of either X chromosome.

Intercuspal distances of the M1 in malocclusions

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The aim of this study is to explore the contribution of the M1 three main cusp intercuspal distances in transversal and sagittal malocclusions. According to cuspal quidance theory molar tooth cusps "work" as quide posts before setting into occlusion during tooth eruption process. M1s are also erupting into the sites determined by deciduous second molars and oral functional forces.

Material and methods: The distances between main buccal (CD1) and mesial (CD2) cusp tips of recently erupted upper and lower M1:s were measured in a group of 2149 children at ages varying from 6 to 12 years. Normal Angle class I controls were compared with different malocclusion groups, transversal (crossbite and scissors bite) and sagittal (distal- and mesialbite). Variance analysis and T-tests according to sex and race (50/50% boys/ girls, 60/40% African –American / Caucasoids) were done.

Results: In crossbites the mandibular M1:s had significantly increased CD1, while in distalbites CD2 in upper molars was reduced. Reduced CD:s were found in subdivision types (unilateral AII malocclusion) on the Angle class II side. The results varied according to race and sex. In mesialbites and scissorsbites no significant results were found.

Conclusions: In critical cusp to cusp situations a malocclusion may follow due to variable occlusal morphology or deviating oral function. Intercuspal dimensions between the main cusps are determined already during the prenatal and perinatal time by genetic and gestational environmental factors.

Are contemporary ethnic groups of the Hindu Kush highlands biologically meaningful populations?: A dental morphometric analysis.

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Ethnic identifications in the Indian subcontinent continue to have social relevance in contemporary society. However, some have questioned whether their social relevance equates with biological distinctiveness, especially in Islamic Pakistan. If such ethnic groups do reflect biologically meaningful populations, then geographically distinct samples of individuals from the same ethnic group should exhibit closest affinities to one another and be dissimilar from geographically proximate members of other ethnic groups. In this study, we test for biological uniqueness among multiple geographically separated samples of specific ethnic groups using both odontometrics and dental morphology. Results obtained from 30 different samples encompassing some 3,000 living and prehistoric individuals confirms that ethnic groups located in the rugged Hindu Kush highlands are biologically meaningful subpopulations. Hence, such ethnic group identifications—at least in this region of South Asia—do represent valid population entities for tracing the biological history of human populations in this region.

Using placental dental eruption sequences in phylogeny

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Elucidating deep phylogenetic splits among placental mammals has been difficult due to lack of morphological characters. Developmental patterns in modern and extinct lineages are a promising new set of data that can be used to understand the phylogeny of placentals and the life-history differences that distinguish clades. Dental eruption sequences are one expression of developmental patterns that can potentially be used in phylogenetic studies.

Based on our current understanding of how different signaling genes operate in the expression of the mammalian dentition, dental eruption sequences were parsed into a series of codable character states based on the relative timing of eruption of different teeth. Using a data set comprising more than 200 partial to complete eruption sequences of extant and extinct placental mammal taxa sampling 19 orders, these characters were mapped onto existing phylogenies. The relative timing of eruption of the canine-incisor complex is the most variable, often differing among closely related species and/or genera. The order of premolar eruption relative to molars is the next most variable part of the eruption sequence, with differences often distinguishing clades nominally recognized at the family or subordinal level. Parsing dental eruption sequences into characters based on developmental units allows the inclusion of even incomplete fossil taxa in reconstructing a clade's history and may provide new insights into the mechanisms controlling the expression of dental development.

New data on dental eruption patterns in early artiodactyls

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Dental eruption patterns are primarily studied for their value in inferring life history variables in living and fossil mammals, but recent work has highlighted the possible phylogenetic importance of eruption sequence data. However, dentitions of juvenile fossil mammals are rare, and there are few data available to broadly test phylogenetic hypotheses. Here we present new data for late middle Eocene (~40 Ma) representatives of three families of tylopod artiodactyls (the clade containing living camels) from southern California: *Protylopus* (Oromerycidae), *Leptoreodon* (Protoceratidae), and *Protoreodon* (Agriochoeridae) from the late middle Eocene (~40 Ma) of southern California.

Living artiodactyls demonstrate patterns of dental eruption that differ from other ungulates of similar size and vary among sampled taxa. Specifically, the majority of artiodactyls erupt their molar dentition prior to erupting the anterior permanent dentition. This pattern is generally associated with relatively rapid growth early in ontogeny, but it is unclear to what extent such fast growth may represent a primitive condition for artiodactyls as a whole or a derived feature of select extant taxa. For the three fossil taxa, we determined the relative timing of molar and premolar eruption; incisors and canines were examined but excluded from this analysis due to small sample size. Molar-premolar dental eruption sequences were inferred from analysis of multiple juvenile dentaries and maxillae. Our data demonstrate that all molars erupt before permanent premolars in *Protylopus*, *Leptoreodon*, and *Protoreodon*, as is seen in ruminant artiodactyls and a pattern associated with relatively fast growth. The consistency of this pattern across sampled extant artiodactyl clades (excluding cetaceans) suggests it is the primitive pattern for this group.

Early incisor development – a new aspect of the mouse odontogenesis model

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It is generally accepted that at around ED (embryonic day) 11.5 in mice, the epithelial thickenings in the developing upper and lower jaws (first branchial arch derivatives) represent the first morphological signs of tooth development. During the initiation of tooth development, Shh (Sonic hedgehog) as well as other signaling molecules are expressed in these epithelial thickenings. We used a combination of histology, 3D reconstructions and WISH analyses (Shh expression) to investigate the fate of these initial epithelial thickenings and their developmental relationship to the lower incisors in a series of detailed staged wild type mouse embryos from ED11.5 to 13.5.

We clearly documented that instead of a single Shh expression domain, widely assumed to be continuously present in each lower incisor area during ED12.5-13.5, several Shh expression domains were present in the lower incisor area in wild type mice. The expression domains differed in their time of appearance and position. They sequentially appeared in two regions in an anterior-posterior sequence during this period. The initial anteriorly located Shh expression region was related to the origin of a rudimentary (prelacteal or deciduous) incisor, while only the later, posteriorly located region corresponded to the prospective lower functional incisor in wild-type mice.

This study sheds new light on the early development of the mouse lower incisor. These findings strongly suggest the necessity to re-interpret previous results based on either morphology alone or on the detection of expressed signaling molecules alone, and offer new insight into the interpretation of existing data in mutant mice.

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Enamel development in Pleistocene orangutans from south China

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In recent years, abundant fossil materials of orangutans were found in south China, which inspired a new perspective on the evolution of late Miocene south China great apes and the origins of humans. Here we observe ultra-thin sections through mesial cusps of Chinese Pleistocene orangutans' upper and lower molars (a total of six) under polarized light microscopy, and the results show that 1) the periodicity of Retzius line in orangutan teeth is 9 days, which is in the middle of living apes range (4-12 days), longer than chimpanzees (6 -7 days), and falls within the range of variation of gorilla (8-11 days). According to the relationship between Retzius line periodicity and body size, we infer that Pleistocene orangutans were medium-sized, between living gorillas and chimpanzees, 2) the rate of enamel secretion in Chinese Pleistocene orangutans is faster than in *Lufengpithecus*, which may be why Chinese Pleistocene orangutan teeth are bigger than *Lufengpithecus* and 3) the lateral enamel formation time is 2.44-2.66 yrs. Chinese Pleistocene orangutans have a longer molar enamel formation time compared to living gorillas and chimpanzees, *Australopithecus*, and some Miocene hominoids.

These results can help us to understand the features of enamel development of Chinese Pleistocene orangutans, which might provide some clues to their life history, adaption and extinction.

Twin studies of dental crown morphology: genetic and environmental determinants of the Cusp of Carabelli

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Dental development reflects environmental and epigenetic modulation of gene expression through time. Examination of phenotypic expression in genetically identical and fraternal twins provides a powerful means to estimate genetic, epigenetic and environmental contributions to observed variation.

Our aim was to determine the relative contribution of the genotype to expression of Carabelli cusp in both primary and permanent maxillary molars (dm2, M1). Phenotypes were recorded using dental models from a sample of Australian twins, collected during an ongoing study of dento-facial development. Dahlberg plaques were used for scoring. The sample comprised approximately 200 twin pairs (100 monozygous, 100 dizygous) with at least partial data for dm2 and M1. Structural equation modeling was conducted using Mx.

A multivariate structural model containing both specific and general additive genetic effects and unique environmental effects was sufficient to describe phenotypic covariation between ages and sides. Heritability estimates ranged from 80%-90%. There was no evidence of a shared (twin) environment effect.

According to Butler's field model, the most mesial tooth within each 'field' shows most stability in size and morphology. It has been proposed that dm2 should be considered as part of the permanent molar series, based upon ontogeny and phylogeny. This is supported by our data – there was a significant transmission of genetic variance from dm2 to M1. Further data are now being collected to improve the power of the model.

This study was funded by the National Health and Medical Research Council.

Geographic variation in the jaws of Holocene *Sphenodon* (Lepidosauria: Rhynchocephalia) demonstrated by landmark analysis

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The tuatara, *Sphenodon*, is a terrestrial reptile now mainly restricted to islands off the coast of New Zealand but it was formerly widespread across the mainland as shown by an extensive Holocene fossil record. Although recent New Zealand (>250,000 km^2) comprises two major islands (effectively separate for at least 120,000 years), and a wide range of environments and biota, the Holocene material has never been surveyed for geographic variation. We landmarked 125 images of *Sphenodon* dentaries from four different localities (North Island: 3, South Island: 1) and after Procrustes fitting performed a principal components analysis. Results show that variation in shape involves the dorsoventral height of the element, shape of the ventral margin and coronoid process, and relative length of the tooth row and posterior process. For example, the jaws from all three North Island localities (e.g. Tom Bowling Bay) are deeper with a more curved ventral margin than those from the only South Island locality (Marfells Beach). This may reflect genetic variation or differences in bone remodeling caused by feeding on prey of different hardness. Discriminant function analysis was able to correctly classify specimens according to locality with an accuracy of 54.4 % (chance alone = 25 %) and to North or South island (North or South) with a success rate of 75.2 % (chance alone = 50 %). The geographic morphotypes do not necessarily represent different species but geographic variation is clearly apparent in this taxon which is widely assumed to be morphologically conservative.

New dental evidence regarding Pleistocene/Holocene Nubian population affinities

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Many anthropologists have, for decades, posited biological continuity in late Pleistocene through recent Nubians. However, consequent dental and skeletal research reveals that regional Holocene samples differ significantly from those at Late Paleolithic Lower Nubian sites of Wadi Halfa and Jebel Sahaba. If the latter samples are representative, then post-Pleistocene discontinuity is implied.

Who, then, were the ancestors of later Nubians? A dental morphological comparison of 12 late Pleistocene through early historic Nubian samples (n=671 individuals) with newly discovered remains from al Khiday, Upper Nubia, may yield an answer. Dating to at least 9,000+ BP, the sample (n=40) may be the first of Late Paleolithic age recovered in 40 years, though the excavators prefer the more conservative "pre-Mesolithic."

Using the Arizona State University Dental System to record traits, and multivariate analyses to assess inter-sample affinities, al Khiday was found most akin to the Holocene samples. It is divergent from Jebel Sahaba. As such, there may be long-term biological continuity, albeit with Upper rather than Lower Nubian late Pleistocene peoples. Of course, it cannot be proven that the al Khiday people were directly related but, assuming dental affinities are indicators of genetic variation, they are minimally representative of what the common ancestor would have been like.

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How did the first teeth work? Quantitative functional analysis of conodont elements

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Quantitative functional approaches to understanding dental functional morphology, such as modelling teeth as tools, complexity and finite element analyses, have hitherto been applied successfully, but have been focussed predominantly on mammalian dentitions. To gauge the generality of the principles derived from these techniques, it is necessary to examine a phylogenetically independent set of dental tools: conodonts constitute an ideal comparative model. Conodonts are an extinct group of primitive marine vertebrates represented in the fossil record by their microscopic teeth: the most primitive dental apparatus known among vertebrates. The group was also of key ecological significance, owing to the abundance and position of conodonts within ancient food webs, and yet knowledge of their diet and feeding is virtually absent. We undertook the first quantitative analysis of conodont tooth function: through analyses of finite element models and sharpness parameters, we demonstrate how conodont teeth were well adapted for food processing, exhibiting morphological convergence with mammals, and we provide constraints on the nature of conodont occlusal kinematics. This work places evolutionary changes in conodont tooth morphology within a functional context, provides new insights into the scaling of dental characters, and permits a broader assessment of functional convergence in feeding structures.

The mammal-like carnassial teeth of *Clevosaurus* and *Tingitana* (Reptilia: Diapsida)

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The Rhynchocephalia are a group of reptiles that diverged from their sister clade Squamata (lizards and snakes) over 235 million years ago. The only living example is the tuatara of New Zealand (*Sphenodon*) but for much of the Mesozoic (220 to about 130 million years ago) rhynchocephalians were globally widespread and morphologically diverse: showing variation in terms of their body proportions, skull structure, tooth arrangements and tooth shape. Correspondingly, members the group pursued a range of ecological niches including terrestrial insectivory, terrestrial herbivory and aquatic piscivory. Using engineering principles I examined the teeth of two taxa: *Clevosaurus hudsoni* from the Late Triassic of the UK and *Tingitana anoualae* from the Early Cretaceouos of Morocco. Both possess teeth with a high tip sharpness, high cusp sharpness, a long labial edge kept sharp by wear, and an lingual valley-like exit structure to permit good fragment clearance. They are also arranged so that they have a positive rake angle and cutting edges that face one another obliquely forming a capture area or notch. They therefore closely resemble the carnassial teeth of many mammals. These sophisticated cutting tools are suited to dealing with material with a high Poisson's ratio such as flesh; as the food is dorsoventrally compressed between opposing tooth rows it expands in the horizontal plane against the blades of the teeth and the work to fracture it is reduced. This contradicts previous suggestions that *Clevosaurs hudsoni* may have been herbivorous and further highlights the dental variation exhibited by rhynchocephalians.

The classification of tooth attachment in tetrapods

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Tetrapods exhibit a wide range of tooth attachment modes. These are usually classified using four categories: thecodonty (teeth have long roots held in sockets by periodontal ligament, e.g. *Homo*, *Crocodylus*, some extinct birds, many non-avian dinosaurs); acrodonty (teeth have no roots and are instead fused to the crest of the jaw bone, e.g. the lepidosaur *Sphenodon*), pleurodonty (teeth are attached to the inside of the jaw bone, e.g. *Iguana*); and subthecodonty (teeth sit in a shallow gutter that has a larger labial wall than lingual wall, e.g. some early diapsid reptiles such as *Petrolacosaurus*). However, the teeth of some lizards and some extinct, transitional taxa are difficult to categorise. This has led to the erection of finer categories such as subpleurodonty or ankylothecodonty, with mixed success. Using a phylogenetically wide sample of specimens we argue that tooth attachment involves a set of distinct characters that, although often linked, should be described and treated independently (e.g. tooth location, root length, height of the labial wall, height and structure of the lingual wall, mode of tooth replacement, and the presence or absence of alveolar septae). There is great diversity present in Synapsida (mammals and their extinct relatives), Archosauromorpha (crocodiles, birds, dinosaurs, extinct relatives) and Lepidosauromopha (lizards, tuatara, snakes, extinct relatives), but it involves different aspects of the component anatomy in each of these clades. Any hypothesis of the evolutionary origins of dental implantation in extant groups must properly take account of the plesiomorphic (primitive) condition observed in extinct taxa.

Can dentine microwear reveal diet? A low-magnification study of enamel and dentine in extant rhinoceros

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This study is the first to systematically test dental microwear on the dentine surface. Our purpose is to evaluate the use of dentine dental microwear as a tool to assess palaeodiet and palaeoecology in mammalian teeth that lack enamel like those of xenarthrans. We chose rhinoceroses as a model group for three reasons: (1) a considerable part of the occlusal surface of their teeth shows exposed dentine; (2) with the exception of *Ceratotherium simum*, there is no major morphological step between the enamel band and the exposed basin; (3) because of their critical conservation status, rhinoceroses are an well studied group in an ecological sense comprising species representing different food preferences and different habitats. Examination of microwear was done on three different sampling loci on each tooth: on the enamel band, in the dentine very close to the enamel-dentine junction, and in the dentine basin. Results show that only the microwear signals of the enamel and of the dentine basin are suitable to distinguish between species and to predict their feeding habits. Interestingly, scratch texture features are most telling for enamel while numbers of scratches and pits are most significant in the dentine basin.

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Dental arch morphology in five Chinese minorities in Yunnan Province.

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Dental arch form in 5 Chinese minorities was metrically analyzed and the results were compared with other Asian and Pacific peoples. Materials were dental impression models of 5 Chinese minorities, Hani, Dai, Naxi, Pumi and Miao in Yunnan Province. They were placed under the system of arm-type 3D digitizer (Micro Scribe 3DX) and the landmarks were plotted. Arch width was represented by 9 parameters and the arch length was represented by 8 parameters with the use of the program of CADKEY2000. Principal component analysis elucidated that general dental arch size of Yunnan Chinese minorities was small and relatively short compared with other Asian and Pacific populations in males and females. They were smaller than Japanese especially in the lower dentition. The arch size and shape of these minorities might depend on their small tooth size. Among 5 groups, Hani had a larger arch, but Miao had a smaller one than other groups. In the sex combined analysis, it was generally clear that male's arch was larger in size and broader in shape in all of the populations studied.

Dental Maturity in 47,XYY Males and 45X Females

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Background: Previous dental studies have given proofs for the direct differential effects of the human X and Y chromosome genes on tooth crown size. Both of these sex chromosomes promote almost equally metric tooth enamel growth. The Y chromosome effect at least on enamel is probably genetic regulation and its effect on dentin growth is definitely greater than that of the X chromosome.

Objective: In the present approach permanent tooth formation in fourteen (14) 47,XYY males or males with an extra Y chromosome and in forty eight (48) 45,X females or females with one X chromosome (Turner syndrome) were studied.

Methods: The determinations of maturation stages beginning from early development were made from dental panoramic radiographs according to revised version of Demirjian's method.

Results: The results indicated delayed dental development in 47,XYY males and in 45,X females advanced tooth maturation relative to population standards.

Conclusions: The lack of the second sex chromosome may thus lead to the advance in dental maturation and an extra Y chromosome to retardation in development. 47,XYY males show increase in tooth crown and root sizes, whereas in 45,X females these metric measurements are reduced in size. In normal males (46,XY) both of these tooth components are larger and delayed in development relative to normal females (46,XX).

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A geometric morphometric analysis of the crown form of the maxillary central incisor.

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Dental traits have been studied over a long period and grossly evaluated using the standard reference plaque. However, grading by subjective observation may result in inter-observer measurement errors. We aimed to analyze crown models three-dimensionally to assess the shovel shape. Micro-CT scanned data of 38 maxillary central incisors stored at two different laboratories were used to create crown models of outer enamel surface (OES) and dentino-enamel junction (DEJ) form. Original crown data were evaluated according to the grade of shoveling into weak and strong groups. Homologous models consisting of the same number of data points were created and the distance matrices between tooth models of OES and DEJ were respectively analyzed by using multidimensional scaling analysis (MDS) and principal component analysis (PCA). Student's t-test was used to compare corresponding scores between the shovel-shaped two groups. The results of a t-test in the OES model indicated significant differences between the two groups. In contrast, the result in the DEJ model did not reveal a statistically significant difference. Our results indicate that geometric morphometric analysis of micro-CT scanned tooth crowns represents a powerful solution for the objective shape assessment of human teeth.

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Intricacies in recording enamel hypoplasia in sheep molars

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Occurrence of enamel hypoplasia has been used as a marker of systemic stress during the period of tooth crown formation in various mammalian taxa, especially primates. In some studies, the macroscopically recorded position of hypoplastic enamel defects along the vertical tooth axis has been utilized to reconstruct the timing of stress events. Recently, this approach has been extended to bovid species with high-crowned cheek teeth. Enamel extension rates in these teeth are, however, unknown. This contribution presents results of light and scanning electron microscope studies on enamel hypoplasia in molar teeth of sheep from various locations and illustrates some aspects that must be considered when recording enamel hypoplasia in the teeth. Our findings indicate a significant variation in enamel extension rate, which is markedly reduced in cervical enamel. Therefore, occurrence of enamel hypoplasia is disproportionately high in this area. A general problem was the partial or complete filling of hypoplastic enamel defects with hyperplastic cementum and/or dental calculus, which hampered the identification of these defects on external inspection and precluded assessment of their depth. Only on sections it was possible to identify the accentuated incremental line (Wilson band) at the base of the hypoplastic defect, which marks the position of the enamel growth front at the time of the insult, and thereby to reconstruct the timing of the stress event causing enamel hypoplasia. Reliable assessment of the timing of stress events affecting tooth crown formation therefore requires histological analysis of tooth sections.

Macroscopic and microstructural features of fluorotic enamel in free-ranging Eastern Grey Kangaroos (*Macropus giganteus*)

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We studied enamel fluorosis in mandibular molars of Eastern Grey Kangaroos inhabiting the surroundings of an aluminium smelter at Portland, Victoria, Australia. Mandibular fluoride concentrations in the individuals (n=7) ranged from 1469 to 11613 mg/kg (ash wt), compared to between 82 and 282 mg/kg for conspecifics not exhibiting enamel fluorosis (n=5) that originated from two unpolluted areas. Fluorotic teeth were characterized by abnormally intense and uneven wear. In contrast to the lustrous and white enamel of control teeth, that of the fluorotic molars was dull and showed a brownish discolouration. Fluorotic enamel exhibited numerous surface defects that by SEM-BSE imaging and light microscopy of ground sections were shown to be partly of a hypoplastic nature (thus indicating an impairment of the activity of secretory-stage ameloblasts), partly of posteruptive origin. The hypoplastic enamel defects were associated with the presence of accentuated incremental lines in the enamel. Enamel defects were often occluded by cementum which, if present, formed the basal portion of the occluding material, and/or by dental calculus. Fluorotic enamel was further characterized by a hypomineralization that was most pronounced peripherally and caused the abnormal wear and the posteruptive loss of outer enamel upon chewing. Where the enamel layer was intact (no posteruptive loss), the peripheral hypomineralized enamel was overlain by a thin surface layer of higher mineral content. In the dried teeth, the hypomineralized enamel formed conspicuous periprismatic gaps and larger clefts. The features of fluorotic kangaroo enamel correspond to those previously described for fluorotic enamel of placental mammals.

Diversity of hypsodonty in mammalian dentitions – construction and classification.

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Hypsodonty is a wide spread phenomenon in mammalian teeth, but it lacks a consistent definition and characterization for all tooth positions and/or taxonomic groups. Hypsodonty describes a specific type of tooth with the crown elongated parallel to the growing axis, a condition which can occur in any tooth position. Hypsodonty is interpreted as the elongation of specific ontogenetic phases during tooth development at the cost of all others in a heterochronic mode. Three parameters are used for differentiation: the specific elongated ontogenetic phase or phases; the degree of hypsodonty (increasing hypsodont and euhypsodont); and the kind of abrasion (balanced wear by an antagonist or free growth). The first parameter is regarded as the most important one. Although the separation of the four ontogenetic phases (I - cusps, II - sidewalls, III - dentine surface, and IV - differentiated roots) is artificial, it allows characterization of the great diversity of hypsodont teeth in six categories: 1) multicusped hypsodont (extended phase I); 2) unicuspid hypsodont (confluent phases I+II); 3) sidewall hypsodont (extended phase II); 4) enamel band hypsodont (phases II+III synchronous); 5) partial hypsodonty (phases II+III+IV synchronous); and 6) dentine hypsodonty (phase III dominant). A synopsis with previously defined types of hypsodonty is given. The new classification is comprehensive, opens the view to the construction of hypsodont teeth, and allows a comparison under evolutionary aspects.

Anatomical variation in the position and number of mental foramina in different extinct human populations.

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Regarding the great implication of the variation in the mental foramen of humans for both the clinical professions and anthropology, the position and the numerical variation of the mental foramen were studied in 10 extinct human populations of different historic times and geography. The material consisted of unselected and unsexed mandibles from different areas in Europe, Middle East, and Japan. The position of the mental foramen was investigated in relation to the mandibular teeth. In addition, the number of multiple and partite mental foramina was scored. In general, a position of the mental foramen beneath the mandibular second premolar was the most common one. The finding that the mental foramen of the Jomon population of Japan was found more posterior than in the other populations supports earlier workers reporting about a more posterior position of the mental foramen in Asian populations. There was a high variation in the frequency of multiple and partite foramina among the populations, which did not suggest any recognizable geographic trend. The relative high frequency of multiple mental foramina in one of the European populations may be linked to the genetic structure of the population, suggesting that the numerical variation of the mental foramen is a useful additional nonmetric trait in population analyses.

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Functional reconstruction of dental arches derived from Occlusal Fingerprint Analysis (OFA)

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Complete or partial dental arch reconstruction with a correct functional interocclusal relationship is still a challenge. Nonetheless, the pattern of attritional facets on the occlusal surface of tooth crowns can assist for physiological crown repositioning, both for clinical applications and for anatomical reconstruction of fossil remains.

In this contribution we exemplary describe a method for functional dental arch reconstructions derived from occlusal fingerprint analysis, and give a perspective for the fields of application.

The upper and lower dental arches of two modern humans and two fossil hominoid specimens were considered in this study. Information of individual antagonistic occlusal contacts were extracted from detailed occlusal wear pattern mapping. The dip and dip directions of each wear facet in the dentition were recorded, and used to reconstruct pro-, latero-, medio-, re-, sur- and detrusive occlusal jaw movements starting from the moment of maximum intercuspation. The spatial distribution of the complementary wear facet pairs constrained the individual position and antagonistic relationship of crowns for dental arch reconstruction. The occlusal plane, intercondylar distance and the displacement of the condylar axis from the tooth position influenced the angles of movements mirrored on the occlusal surface of a crown. Finally, the reconstruction of phase I, maximum intercuspation and phase II tooth contacts was verified in the Occlusal Fingerprint Analyser (OFA) software. Accordingly, we introduce here the use and the potential of a virtual tool for occlusal analysis, the OFA software, for the recording and quantification of occlusal relationships and movements derived from collision data of virtual crown surface models.

The Occlusal Fingerprint Analyser software programming is financed by the German Research Foundation in the frame of the DFG Research Unit 771 “Function and performance enhancement in the mammalian dentition phylogenetic and ontogenetic impact on the masticatory apparatus”.

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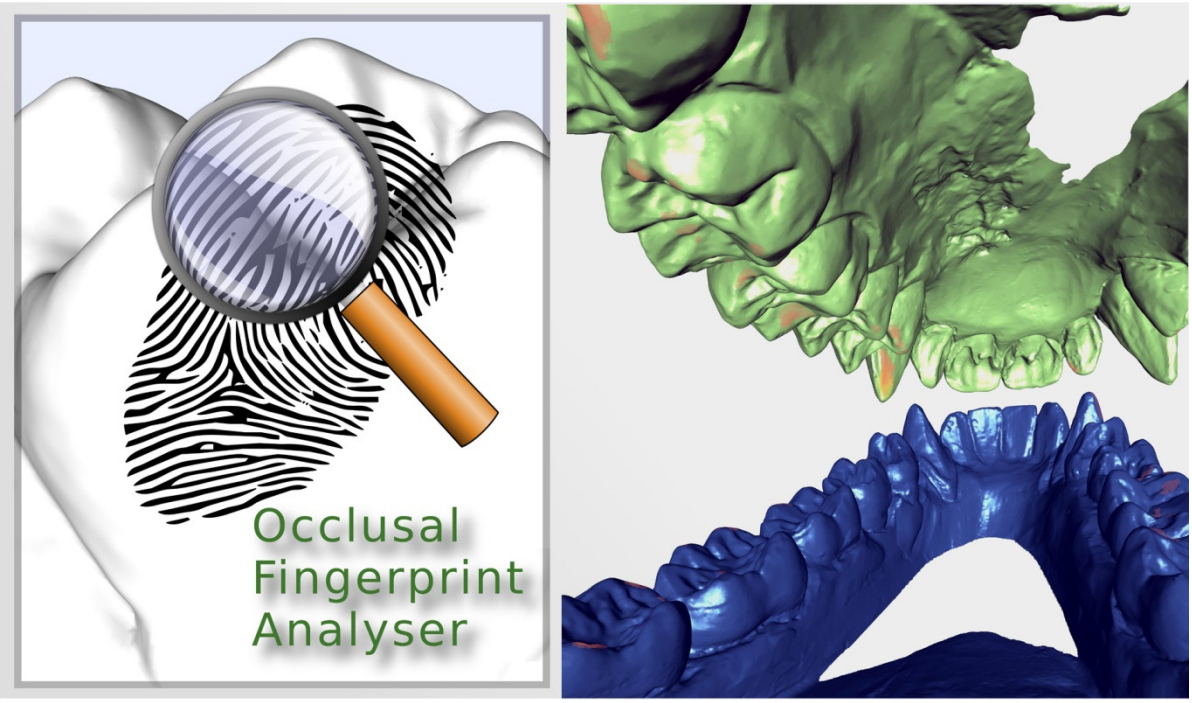

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Mechanical behaviour of incisors and dietary specialisation in cercopithecine primates.

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Primate teeth are adapted to performing specific feeding functions. Research has shown that the enamel cap morphology plays a crucial role in controlling the mechanical behaviour of the crown. Incisors are particularly interesting in terms of structure-function relations as their role in feeding is that of the "first bite". However, little is known how incisor crown morphology and enamel distribution is related to tooth deformation. We examined the mechanical behaviour of mandibular incisors and their constituent tissues in the cercopithecine primate *Macaca mulatta* under near-physiological loads using experimentally validated finite element models. Unlike leaf-eating colobines, in cercopithecines enamel is only present on the labial surface of the mandibular incisors overlaying the more pliable dentine. This presumably enables cercopithecines to maintain a sharp incisal edge adapted to fracture tough food objects. The simulation results concurred with experimental data in that, although compressed along the longitudinal axis, deformation in the incisors mostly occurred in the lingual direction and orthogonal to the load direction. Our results furthermore show that this deformation pattern does not change in incisor models with artificially added enamel on the lingual crown surface. These findings therefore reiterate the importance of whole-crown morphology in directing deformation behaviour of teeth and indicate that the distribution of enamel on the incisor crown of the cercopithecines is mainly intended to produce a desired working edge. The results of our study provide insights into the adaptive basis for dental morphological variability and dietary specialisation in primates.

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Genetic regulation of enamel mineralization

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The evolution of biomineralization has required the advent of new genetic programs and/or the modification of preexisting programs. A revolutionary advance in vertebrates was the ability to undertake controlled precipitation of calcium phosphate-based minerals, particularly hydroxyapatite. Surprisingly little is known about the cellular machinery and regulatory processes involved in the mineralization of hard tissues. In this study we have exploited the two-step process of enamel formation to achieve the first comprehensive molecular survey of the enamel organ by microarray analysis to identify the genetic events driving enamel mineralization. Using the rat incisor as a model, we isolated enamel organ cells from secretory and maturation stages. Over 540 genes were identified as being ≥ 2-fold up- or down-regulated during maturation, the vast majority of which are novel to this field. Our results suggest that the functional switch from secretion to maturation involves a profound change at transcriptome level, and that many of the affected genes can be assigned to the areas of matrix turnover, calcium handling, pH and ion regulation. We also studied enamel phenotypes in mice and in pigs associated with disruptions to genes involved in mineralization. We here describe the nature of changes in the rat transcriptome and that of abnormal enamel phenotypes.

The probability of being average: estimating age from developing teeth

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The aim of this study was to look afresh at the interpretation of estimated age from tooth formation stages by illustrating the problems and limitations and providing several new approaches. Most tooth formation stages show considerable age variation, with some children reaching a tooth stage several years earlier than average and some children reaching a tooth stage considerably later than average. Mean estimated age is appropriate for children who are average maturers, but the vast majority of individuals are not average. This suggests that a point estimate is inappropriate. Results from recent reference studies of confidence intervals (51% and 95%) of estimated age for Moorrees (N=1050) and Demirjian (N=9371) tooth formation stages of permanent teeth will be presented. The likelihood ratio of being on or other side of an age threshold, given a tooth stage will also be presented. These methods of expressing estimated age are tools to improve understanding of the developing human dentition.

Regional variations in Hunter-Schreger Band density in human premolar and molar teeth.

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Hunter–Schreger Bands (HSBs) are visible on cut or fractured enamel surfaces when viewed under reflected light. Their appearance is caused by the interaction of incident light and the varying directions of examined prisms. HSBs are thought to increase fracture and wear resistance of enamel.

Objectives: To investigate the regional variation in the HSB densities within human premolar and molar teeth.

Methods: Teeth with intact crowns (40 maxillary premolars, 40 mandibular premolars, 10 maxillary molars, 10 mandibular molars) were sectioned in the buccolingual and mesiodistal planes, mounted and the amelodentinal junction (ADJ) subdivided into segments to facilitate counting of HSBs. Under reflected light and x10 magnification, the numbers of HSBs in each segment were counted and HSB packing densities calculated (number of HSBs per mm of ADJ).

Results: The following HSB packing densities were observed: maxillary premolar: occlusal surface= 13.8 HSB mm^{-1}, cervical region of palatal surface= 5.4 HSB mm^{-1}; mandibular premolar: occlusal surface= 12.6 HSB mm^{-1}, cervical region of lingual surface= 4.3 HSB mm^{-1}; maxillary molar: occlusal surface= 14.6 HSB mm^{-1}, cervical region of buccal surface= 3.6 HSB mm^{-1}; mandibular molar: occlusal surface= 14.8 HSB mm^{-1}, cervical region of distal surface= 2.3 HSB mm^{-1}. The differences in HSB packing densities were significantly different ($p<0.05$) between the segments examined within each tooth group.

Conclusions: Significantly greater HSB packing densities were observed in occlusal regions of premolar and molar teeth compared to cervical regions. This suggests that HSBs are structural modifications within enamel that optimise its resistance to wear and fracture.

Human deciduous canine and incisor crown formation time: preliminary results.

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Histological analysis of tooth enamel incremental markings provides an accurate method for reconstructing crown formation time. These reconstructions have several applications in both bioarchaeology and biological anthropology. Formation time can contribute towards hominoid age-at-death estimations, which provides a base line from which to compare and evaluate the timing of dental development. Good data already exists for permanent teeth, but formation times for deciduous teeth have been less reported in the literature, especially for anterior teeth. This project will reconstruct crown formation time, and other aspects of enamel growth, from histological analyses of deciduous anterior teeth. Here I report preliminary results for mandibular canines (dc_1) and lateral incisors (di_2).

Incisors and canines were extracted (n=21) from archaeological samples of modern human juveniles. Daily enamel secretion rates (range of 2.72-4.80µm) were calculated from short period markings and used to reconstruct cuspal formation time. Lateral enamel formation time was calculated from the periodicity of long period markings for three teeth (range of 6-7 days). For the remaining sample, lateral formation time was reconstructed from enamel prism lengths divided by local mean secretion rates to navigate between accentuated markings.

Lateral incisor crown formation times ranged between 250 to 338 days. Canine formation times ranged between 380 to 527 days. When recalculated as chronological age since birth, mean values were greater compared to mean postnatal age of enamel crown completion reported from other methods. Ongoing work will compare enamel growth between deciduous mandibular and maxillary anterior teeth.

A pilot study of dentine thickness measured from isolated human maxillary premolars.

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Coronal dentine is known to be significantly thicker in males compared to females. The aim of this study was to explore the bucco-lingual dimensions of human maxillary premolar in males and females. If a measure of dentine thickness could discriminate between males and females, this would have application to help identify sex in forensic cases, mass disasters and archaeology. The sample studied consisted of unworn premolars from 41 skeletal remains of known sex from the Hunterian Museum, Royal College of Surgeons, England and the Natural History Museum, London. Data were collected from 13 males and 8 females for the first premolar and 19 males and 11 females for the second premolar. Digital photographs were taken parallel to the occlusal surface. Intercuspal distance and maximum bucco-lingual distance were captured using ImageJ and the ratio calculated. Results were compared using a t-test and show that for both upper premolars, the ratio was smaller in males than females; however this was not significantly different to zero. The ratio for P1 was less than P2 in males, but similar in females. These findings show that dentine thickness, measured in this way, is not significantly different and cannot discriminate between the sexes in this sample.

Lead levels in teeth as a measure of life-time lead exposure in children

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The toxicity of lead to human health has been known for many years and can have a potentially irreversible effect on a child's cognitive development and social behaviour even at very low levels of exposure. The usual test for lead exposure is to assess blood lead level (BLL), but this indicates only recent lead exposure. This study aims to develop a method to assess long term cumulative lead exposure using tooth lead levels.

Two deciduous molars each were collected from 15 children aged 6-8 years living in Northeast England. Using histological sections, the distribution of lead in the different growth layers was quantified by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). BLLs were measured using ICP-MS. Incremental growth lines in enamel and dentine are used to investigate the age of exposure at each sampling point.

Blood lead levels ranged from 0.5-6.8µg/dl, and none of the children had a BLL above the WHO threshold of 10µg/dl. Calcium normalised lead ratios (^{208}Pb:^{44}Ca) were measured as an indication of lead body burden and were found to vary systematically across individual teeth. Comparatively low ^{208}Pb:^{44}Ca ratios were determined in enamel; higher ratios were found in dentine. Preliminary results indicate that consistent ratios at the same time interval were observed in dentine, but which rapidly increased on approaching the pulp cavity.

The histological dating of growth areas of milk teeth in combination with LA-ICP-MS analysis is likely to be useful methodology in establishing the history of lead exposure in children.

Premolar root variation in apes and its implications for hominin systematics.

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Variation in premolar root morphology plays a central role in hominin systematics and the application of microCT enhances our ability to examine this trait in the fossil record. However, the degree of expected variation in root form in a fossil hypodigm is poorly understood. The goal of this study is to document variation in premolar root morphology in a large sample of *Pan*, *Gorilla*, *Pongo* and *Hylobates* to establish expected levels and types of variation in living apes as a benchmark for fossil hominin taxa.

High resolution computed tomography was employed to ascertain external root shape and root canal configuration of each premolar. CT scans of mandibular/maxillary premolars representing 51 *Pan troglodytes verus*, 10 *Gorilla gorilla*, 13 *Pongo pygmaeus*, and 13 *Hylobates muelleri* were segmented to produce virtual models. Root and canal numbers were recorded for each specimen; measurements included root volume and surface area, standard linear dimensions of roots, and a landmark dataset capturing cervix shape. Geometric morphometrics, PCA, Kruskal-Wallace and Mann-Whitney statistics were used to assess correlations between root/canal number, tooth size and jaw size within each species.

The results indicate interspecific differences in the degree of variation in root form and canal number depending on premolar position. A relationship for certain metrics was found between tooth size and root/canal number. Interestingly, the correspondence between root/canal number is not always clear from external examination, demonstrating the importance of including canal number and configuration when characterizing root morphology in extant and fossil taxa for the purpose of taxonomic discrimination.

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Morphological similarities and differences in human and *Pan* mandibles: functional implications

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Numerous studies on primates have found that, independent of the species, there is a strong correlation between body mass, mandible length and width. However, data on mandible growth trajectories indicates that linear dimensions should be stable intra-species but different inter-species. Therefore, scaling the mandible to body mass, while useful in allometric studies, appears to be less appropriate for the study of interspecific differences. In the present work we normalized a large sample of *Homo sapiens, Pan troglodytes* and *Pan paniscus*, to a common overall teeth-mandible volume. This method allowed us to identify disparities in growth trajectory, with particular emphasis on the stability of the cranial base width, while accounting for the teeth and mandible as a functional unit. Our results indicate that: 1) maximum antero-posterior mandible length is highly conservative, despite the differences in symphysis orientation; 2) the position of molars and premolars are similar, but there is a high variation in anterior teeth size and position; and, 3) intercondylar breath is ontogenetically constant intra-species, but in humans it is greater than *Pan*. The shape relationships we found on the toothed mandibles of modern hominids reveal tight similarities between the species studied, with the exception of the maximum intercondylar breath and anterior teeth morphology. On the light of this data we hypothesize that these morphological differences should account for functional discrepancies observed between *Pan* and *Homo*.

Tooth cusps feel the force

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A model system in which to study the developmental mechanisms of morphological change is the mammalian dentition. Teeth develop through an epithelial-mesenchymal interaction between oral ectoderm and neural crest-derived mesenchyme. Tooth shape is controlled by embryonic signaling centers, the enamel knots, via differential growth and folding of the epithelium. Models of the tooth development predict a role for mechanical forces in the growth of the epithelium, and therefore, in the formation of shape. Empirical data has shown that the enamel knots produce signaling molecules that stimulate the proliferation of the underlying mesenchyme. We examined the growth dynamics of the mesenchyme during the development of mouse molars to test whether the mesenchyme has a passive or an active role in shaping the tooth epithelium. Using computed tomography, we measured the density of mesenchyme as a proxy for force by the mesenchyme on the dental epithelium. We then generated three-dimensional reconstructions of the embryonic teeth to see whether these differences in mesenchymal density could predict epithelial morphogenesis and the formation of tooth cusps.

Carabelli's trait in 47 XXX females and 48 XXXX females.

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Background and objectives In order to observe relationships between tooth crown traits and X chromosomal disorders in humans, we investigated Carabelli's trait and Hypocone reduction of maxillary first and second permanent molars in females with one and two extra X chromosome.

Methods and subjects We obtained the data from dental casts belonging to Professor Lassi Alvesalo's Kvantti research project on sex chromosome abnormalities in Finland. The subjects comprised 5 47,XXX females, 2 48,XXXX females and 141 female normal controls from a rural community on Hailuoto island in Finland. Carabelli's trait was scored into three grades in Dahlberg's P12 (1956): grade (–) – smooth surface, grade (±) – pit or furrow, and grade (+) – slight protuberance or cusp. Hypocone reduction was classified into two classes in Dahlberg's P9 (1951): a four-cusp pattern and a three-cusp pattern.

Results The result showed that 47,XXX females and 48,XXXX females have higher frequencies of Carabelli's trait and of four-cusp pattern in M1 and M2 than control females. The statistical association between the expression of Carabelli's trait and four-cusp pattern were found to 47,XXX females, and 48,XXXX females relative to control females in M2.

Conclusions Our result suggests that the additional X chromosome genetic material causes the higher frequency of the Carabelli's trait and four-cusp pattern and has influence on the patterning in cusp number. The possible association between Carabelli's trait and enamel thickness is discussed.

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Quantifying occlusal topography and complexity in non-ruminating mammals

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A vast amount of mammalian tooth shapes and species-specific constructions are described in which the non-ruminating ungulates show diverse herbivorous adaptations and occlusal topographies. In order to understand tooth function and masticatory processes, this study focuses on quantifying functional traits within non-ruminating ungulates. We test the following hypotheses: (1) the pattern of occlusal topography is correlated with dietary behaviour and (2) functional gradients within the tooth row are linked with chewing dynamics and efficiency. Thus, we quantify the complexity of the topography in 54 individuals of the following 8 taxa: *Equus grevyi* and *Equus africanus* (Equidae), *Ceratotherium simum* and *Diceros bicornis* (Rhinocerotidae), *Hippopotamus amphibius* (Hippopotamidae), *Hylochoerus meinertzhageni* and *Phacochoerus aethiopicus* (Suidae), *Tapirus terrestris* (Tapiridae). 3D models of upper post-canine tooth rows are generated using the topometric digitisation system smart*SCAN*^{3D} (Breuckmann, Meersburg, Germany). Terrain analysis (Geographic Information System SAGA) and semi-automated 3D data acquisition tools (PolyWorks, InnovMetric Software Inc., Québec, Canada) are implemented to extract functionally relevant features of the occlusal surface. A mesio-distal increase of enamel-dentine (E/D) ratio in both premolars and molars is detected reflecting the tooth eruption sequence but additionally representing a functional compensation strategy for wear induced loss of structures. E/D ratio and mean slope correspond to the dietary trait with high E/D ratios indicating abrasive diets and large reliefs corresponding to a browsing strategy.

Nonmetric tooth crown traits in a Sri Lankan aboriginal Vedda population

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This study was conducted to determine the frequencies of non-metric tooth crown traits of Vedda of Sri Lanka and to investigate the affinities of these morphological variations with those of other world populations. Fifty dental plaster casts were observed. The Arizona State University dental anthropology system was adopted for classification of the 13 traits observed. The results were compared with those of other world populations. Using the frequencies of 13 traits, Smith's Mean Measure of Divergence was calculated to determine inter-population distances. Affinities among the Vedda and other world populations were expressed in two dimensions of the principle coordinate analysis. Cusp number in mandibular second molar and hypocone absence in maxillary second molar had the highest frequency among the 13 traits. Shoveling, double shoveling in the maxillary central incisor and deflecting wrinkle in the mandibular first molar had the lowest frequency at 0%. The principal coordinate analysis showed that Sino America and Western Eurasia populations were separated in negative and positive directions in the first principal coordinate axis. Vedda located with the Western Eurasia population groups. Sahul and Sunda Pacific populations located in the intermediate position between Sino America and Western Eurasia. The dental phenotype of Vedda has close affinities with those of early South Asian populations. They are distinctly different from Sino American and Sunda pacific populations. Vedda shows closer connection to Sahul Pacific and South African (Bantu) populations.

Root lengths in the permanent teeth of 45,X females

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Background: Studies on permanent and deciduous tooth crown size and structure in relatives and individuals with sex chromosome anomalies have given proofs that the X chromosome affects to enamel formation, root length and crown and root morphology. Results on 45,X females have shown reduced enamel thickness and short roots in addition to extra root components in some instances relative to normal women.

Objective: Here we report on permanent root lengths in females with one X chromosome (45,X) and their female relatives and normal women.

Methods: The study group consisted of 97 45,X females, 32 sisters, 28 mothers and 45 women population controls from Kvantti research project. Root length measurements were made from panoramic radiographs on both sides of the jaws on each available instance.

Results: The results showed significantly shorter root lengths in 45,X females in all measured teeth relative to population control women. The relative females can be considered normal population and their root lengths were shifted towards the aneuploids in relation to general population. The difference in root length in 45,X females relative to their sisters was greater than that to their mothers.

Conclusions: These results accord with the earlier findings on short root lengths in 45,X females. There were no significant differences in root lengths between 45,X and 45,X/46,XX females which is close to the findings in their mesio-distal tooth crown size.

The prevalence of Torus Palatinus in Klinefelter syndrome (47,XXY)

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The previously reported female predominance in the occurrence of Torus Palatinus (TP) supports the concept that at least part of the genetic determinants of the liability for TP resides on the X chromosome. The aim of the present study was to determine the expression of TP in males with Klinefelter syndrome (47,XXY) and to compare the occurrence of TP between subjects with XY-, XX- and XXY- sex chromosome constitutions.

The study population consisted of adult males with Klinefelter syndrome (n = 43) and female (n = 143) and male (n = 67) controls with normal chromosomal constitutions from Kvantti project. The assessment of the expression of TP was done by finger palpation during the clinical examination by one person (LA). The tori were classified according to their size into groups of small, medium, large and extra large.

Males with Klinefelter syndrome (93%) had TP statistically significantly more often than female (71%, $p < 0.01$) and male (56%, $p < 0.0001$) controls. Female controls had TP more often than male controls ($p < 0.05$).

Conclusions, The frequency of TP increases from XY- to XX- to XXY- sex chromosome constitution suggesting that not only the presence of an extra X-chromosome but also the presence of an extra Y-chromosome influences the expression of palatal tori. However, the X-chromosome seems to have a greater effect.

Cranial base, upper face and tooth size interactions in two Finnish male groups.

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The reduction in human tooth size and craniofacial skeleton within the last 10000 years has diminished the robusticity of human face. The craniometric analysis demonstrates that the Finns posses North European craniofacial configuration although prehistoric features may be found in Finnish faces. One reason to that may be that settlers of the country have been hunters and gatherers and Finland has always been a sparsely populated country. Modern genetic studies have shown the regional differences among the Finns. Although Y-haplotype frequencies are different, N3 common in eastern Finland and I1i in western Finland, a male-biased gene flow from Scandinavia to western parts of Finland may explain the differences between eastern and western Finnish males. In this study we compare craniofacial and dental structures and relationships between them in two Finnish male groups. The material was collected at Kuopio University on the - 80s. Tooth size and craniofacial measurements were analysed. Western Finnish males seem to have higher tooth crowns of front teeth. Eastern males seem to have wider lower jaw. There were some contrasting results in correlation tables between upper face and cranial base structures and between tooth size and craniofacial dimensions. We suggest that tooth size differences and different relationships in facial structures is an evidence of differences in genetic background between eastern and western Finnish males.

Sexual Dimorphism in Human Teeth? A questionnaire-study to check the clinical relevance

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There are many morphometric studies that show a sexual dimorphism in human teeth. We wanted to know, in how much these differences can be practically perceived. So, can the sex of an individual be determined, when only the anterior teeth of are visible? To this end, 50 intraoral photographs, showing the front tooth region of women and men (age ranged from 6 to 75 years), were at random arranged in actual size on a questionnaire. The lip region was covered in each case. Except "female" and "male" one was able also to mark "?" if undecided. The questionnaires were distributed to 50 expert test persons (dentists, dental technicians, dental-medical professional employees, students of the dental medicine) and to 50 laymen and were all available for the evaluation. As a result, the statistical evaluation showed that in most cases the true gender could only be recognized correctly by one half, and wrong by the other half. The true gender was recognised on single photographs to a maximum of 76%, while it was wrong to 69% on other photographs. It can be concluded that a sexual dimorphism of human teeth - although measurable morphometrically - could not be recognised visually on the basis of photographs of the frontal tooth region. It is clinically relevant that neither experts from the dental-medical occupational field nor laymen could clearly distinguish female from male teeth.

Relative dental growth in African pygmies.

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Diagnosis of hominid species based on patterns of dental growth has been challenged by the lack of knowledge of dental growth variation in modern humans. Chronology is lacking in most non-occidental societies and the permission to carry out serial sections in the dentition of several individuals in an archaeological population is in most cases refused. Thus, relative growth stages of teeth in a dentition become (again) the tool to assess dental growth variation among modern human populations. Among forager populations, African Pygmies represent one of the most interesting and least acculturated groups. Furthermore, short adult stature is certainly the result of some particular pattern of growth. The knowledge of relative dental growth in African pygmies can reveal some aspects of modern human variation. Political restrictions and logistical constraints meant we were unable to radiographs living individuals, thus we carried out our study on non-adult individuals housed in public collections. Although the number of immature individuals studied is very low, it is interesting to note that except for M3, important differences are not observed. Although short stature reveals a particular growth pattern in pygmies, the consistency in the relative dental growth would indicate a solid genetic basis for dental growth in modern humans.

Is tooth size altered in opposite-sex dizygotic twin pairs, reflecting possible hormone diffusion in utero?

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Studies in rodents and humans have suggested that masculinisation of females and feminisation of males can occur between fetuses in utero due to hormonal diffusion. Opposite-sex twin pairs provide a useful model to study the effects of prenatal hormone diffusion on tooth size. The aim of this study is to determine whether primary and permanent tooth size is altered in females and/or males from opposite-sex dizygotic (OSDZ) twin pairs compared with same-sex monozygotic (SSMZ) or dizygotic (SSDZ) twins. Methods: Female sample: 44 OSDZ females, 39 SSDZ females, 52 MZ females; and male sample: 44 OSDZ males, 42 SSDZ males, 56 MZ males; aged from 4.1 to 16.5 years. Serial dental models of primary, mixed and permanent dentitions were used. Mesiodistal (MD) and buccolingual (BL) crown diameters, crown heights (CH) and intercuspal distances (IC) of upper central and lateral incisors, canines, second premolars, first and second molars and lower central and lateral incisors, canines, second premolars, first and second molars were measured to an accuracy of 0.1mm using 2D image analysis system. OSDZ females were consistently larger by approximately 1-3% in MD and BL dimensions for permanent teeth compared with other groups but CH and IC dimensions did not show the same pattern. No systematic trend was found in either dentition of the male groups. This effect may be related to circulating male hormones in utero.

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A chart to summarize mesiodistal and buccolingual diameters: Dental Proportion Chart

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Mesiodistal and buccolingual diameters are primary measurements in odontometric studies. The measurements are often expressed as indices (crown module and crown index, etc.) aimed at summarizing occlusal form and deriving shape variables. The crown module is the average diameter of the crown in a particular tooth class, and the crown index is buccolingual diameter expressed as a percentage of mesiodistal diameter. To evaluate class changes of dental measurements, charts ordinarily include two coordinates, tooth category as the x-coordinate and a dental measurement (mesiodistal and buccolingual diameters, root length, etc.) as the y-coordinate. It is difficult, however, to visualize size and shape together in such a way that comparisons can be made between sexes and among populations. In this context, a Dental Proportion Chart (DPC) was developed to evaluate tooth class changes in size and shape. The DPC includes scales for size (mesiodistal and buccolingual diameters) and shape (crown module and crown index) on a single graph. The DPC shows both the magnitudes and proportions of the dental measurements simultaneously and thus permits a relatively simple approach to visualizing relationships of dental characteristics between sexes and among proportions. The basic concept of the DPC has already been adopted in a chart to evaluate body composition. The present paper describes the development and application of the DPC.

Toothcomb function and use in wild ring-tailed lemurs: Implications for the evolution of the prosimian toothcomb.

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The structure, function, and evolution of the prosimian toothcomb have received much attention over the years, with various workers espousing feeding, grooming, and/or scraping as the primary selective pressure leading to this unique dental structure. However, comprehensive data on its actual use in living, wild primates are rare. Here we present information on the function of the toothcomb in a wild population of ring-tailed lemurs (*Lemur catta*), from southwestern Madagascar. Across nearly a decade of field studies, we have collected detailed data on toothcomb wear and damage, ecto-parasite load, and individual health. Based on a sample of 103 individuals, our data indicate that toothcomb wear shows a strong positive correlation with increased parasite load ($p < .035$), parasite-caused hair loss ($p < .04$), and that older individuals demonstrate greater toothcomb wear ($p < .0001$) and higher parasite loads than all other age classes ($p < .001$). Longitudinal data also show dramatic increases in toothcomb damage and tooth loss in as little as one year. Once tooth loss occurs in the toothcomb, the remaining teeth rapidly become nonfunctional (loose) and are eventually lost. With toothcomb damage, "hairballs" can also form in the comb, leading to excessive plaque build up at the tooth base that can lead to subsequent tooth loss. In light of recent discoveries indicating the presence of functional toothcombs in early Cenozoic fossil primates, our data on the importance of grooming in living prosimians suggest that this function was likely a significant variable in the evolution of this dental feature.

Paranthropus and *Homo* mandibular premolar morphology: a comparative model in sympatric primates

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Dietary specialization among sympatric hominins has been proposed as an explanation for the dramatic differences in postcanine morphology in *Paranthropus* and *Homo*. Molarization of the crown of the last mandibular premolar is a distinctive feature of the megadont hominins, however its potential functional/dietary significance is untested. Sympatric extant primate communities provide suitable morphological and developmental models for understanding premolar molarization in fossil hominins. We sampled postcanine crown and root morphology from *c.*150 callitrichid, cebid, and other primate individuals from the collections of the National Museum of Natural History, Smithsonian Institution. The sample included closely-related sympatric species with known dietary niches. Postcanine occlusal morphology was compared using linear and areal measurements based on enlarged photographs, and postcanine root morphology was compared using linear and areal measurements taken from plain radiographs and CT scans. P_4 linear and areal measurements vary independently of body size and crown area correlates more closely with root profile area in molars than in premolars. Principal components analysis of occlusal morphology suggests that sympatric species vary significantly in their premolar crown morphology. Results of this study of premolar morphology in closely-related and sympatric primate species can be used to develop hypotheses about the phylogenetic and adaptive significance of the premolar morphology of megadont archaic hominins.

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Three dimensional occlusal surface analysis of dryolestoid molars (Mammalia, Cladotheria)

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The “primary trigon” and trigonid of the pretribosphenic dryolestoid molars are arranged in a reversed triangular pattern. During the chewing cycle the lower molars slide into the embrasures between the upper molars. The buccally oriented groove between the trigonid and the unicuspid talonid of the dryolestid lower molar is homologous to the hypoflexid of the tribosphenic molar. In tribosphenic molars the hypoflexid is more steeply inclined but less involved in occlusal contacts. In the hypoflexid of dryolestid molars, shearing is prominent during the chewing cycle, when the paracone slides buccally along the guiding groove. The hypoflexid inclination of about 35° indicates a shearing function accompanied by a crushing component. Striations near the hypoflexid base show a higher isotropy than striations near the tip of the protoconid, reflecting the guiding function of the hypoflexid groove. Two directions of striations occur which differ about 10°. This indicates that the lower molar moves in two phases into occlusion during the chewing cycle: an initial unguided puncture-crushing phase and a subsequent guided shearing phase before full centric occlusion. A grinding phase after centric occlusion that is typical for tribosphenic molars does not occur in dryolestids. During the evolution of the talonid basin, the shearing area of the hypoflexid was displaced buccally and rotated in mesial direction. In combination with the formation of the talonid basin a functional shift in the chewing cycle from shearing to grinding occurred and the hypoflexid lost the guiding function and its role as the main shearing area.

Topographical analysis of late Miocene catarrhines from Nakali in Kenya.

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One of the most interesting issues for research on the fossils is to shed light on ecological reconstruction of these fossil species. Dental remains can be a very good indicator for dietal adaptation of the species. The topographical analysis using the geographic information system for molars can tell us general diet pattern. Higher occlusal relief and longer shearing crests indicate more folivorous diet. And lower occlusal relief and shorter shearing crests or larger occlusal basin indicate more frugivorous diet. Nakali, a Late Miocene fossil site in Kenya, had a great diversity of primates. Two species of large hominoids, at least three species of small non-cercopithecoid catarrhine, and several old world monkeys include colobine monkey have been recovered from Nakali. There would be food segregations among Nakali primate species. The purpose of this study was to investigate dietal adaptation of Nakali fossil primates using the topographical analysis for outer morphology of molars, and to compare with living African cercopithecoid primates. Colobine monkey from Nakali had higher occlusal relief and longer shearing crests than other species from Nakali or living guenons but lower occlusal relief and shorter shearing crests than living colobus. This early colobus already had more folivorous diet than living guenons or other species from Nakali.

Mandibular premolar enamel-dentine junction shape variation in apes as a comparative context for hominins

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Mandibular premolar crown morphology plays a central role in hominin systematics. This role has increased with the availability of micro-computed tomography which can document, in fine detail, the relative contribution of the dentine crown and enamel cap to the premolar crown shape. The comparative context for variation within hominins can be found within the extant apes, however, the particular aspects of crown structure which vary among apes remain poorly characterized.

In this project we examine the morphology of the enamel-dentine junction (EDJ) among apes to 1) assess its distinctiveness among species, and 2) to characterize variation in cervix shape, crown height, relative dentine horn height, and dentine horn spacing. CT scans of mandibular premolars representing 10 *Pan troglodytes*, 10 *Gorilla gorilla*, 10 *Pongo pygmaeus*, and 10 *Hylobates muelleri* were segmented to produce models of the EDJ. A geometric morphometric analysis was conducted on a landmark dataset that captured the shape of the cervix, primary dentine horns and the marginal ridge. Canonical variates analysis was used to determine the reliability of species classification and digital models of the average shape of each species were used to visualize species-specific aspects of EDJ shape.

The results confirm previous findings that, like lower molars, premolar EDJ morphology is taxonomically distinctive among hominoids. With respect to the presumed primitive morphology, gorillas appear the most derived with a marked increase in dentine horn height and topographic relief. The EDJ shape among hominoids provides a comparative context for interpreting the subtle shape variations distinguishing fossil hominins.

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Weaning and dental development in a seasonal world.

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The field of life history works to understand what shapes the life plans of organisms. Age of weaning has a central role as a measure of reproductive output for mammalian species. Because mammalian offspring must have teeth to be weaned, it is reasonable to expect regularities between tooth emergence and weaning. The present study, which extends previous work, compares age of emergence of the last deciduous and first permanent teeth to age of weaning for 55 species of eutherian mammals from Primates, Artiodactyla and Carnivora, among other orders. Initial work with small samples of primates found a 1 to 1 correspondence of emergence of first permanent molar (x) with weaning (y), i.e., that x≈y. As more data became available, however, it became clear that the relationship holds over a limited range in x. Deviations from the expectation that x=y include stair-stepped grades in weaning ages clustered at one month, three months and one year and a virtual cut-off at one year for most extant mammals. These grades are understandable as the strong influence of lunar, seasonal and annual cycles in determining workable reproductive cycles. Yet broadly speaking, eruption of the first permanent molar continues to bisect mammals into those that wean early or late compared to skeletal development; comparisons also demonstrate clear dietary guilds and minimal tooth kits for weanling mammals. Deviations from the simple model are as revealing as conformity.

Daily secretion rates, prism paths, and cuspal formation times in hominoid molars

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Tooth microstructure is critically important for the study of development, as age at death can be precisely and independently determined from juvenile dentitions, and primate dental development is correlated with aspects of life history (overall pace of growth and reproduction). The past three decades have been characterized by an increasing number of reports on dental tissue secretion rates and crown formation times in many fossil and extant primate species. While the fundamental temporal nature of dental microstructure is well established, numerous quantitative approaches have been employed, complicating attempts to synthesize these time-consuming studies. Here we employ a diverse molar sample to assess daily secretion rates (DSRs), prism paths, and cuspal formation times, using both light microscopy and synchrotron virtual histology. We find that DSR calculations are influenced by the choice of position within the cusp, and the clarity of short-period features (cross-striations, laminations, intradian lines), leading to interobserver error in some instances. Reported differences in average cuspal DSRs among great apes are not evident when DSR is quantified by a single observer from prisms that run from the dentine horn tip to the first imbricational Retzius line. Virtually-segmented prism paths suggest that cuspal prisms do not follow spiral 3D geometry; paths vary considerably within and among hominoids. Thus the commonly-employed path length correction factor (1.15) derived from modern human enamel is not appropriate for hominoid cuspal formation time calculation. Consideration of these factors will allow more accurate DSR and cuspal formation time estimation, as well as age at death determination.

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Shh expression in the lower incisor region during the early development of Tabby mice

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The tabby (Ta) syndrome in the mouse is homologous to X-linked hypohidrotic ectodermal dysplasia in humans and includes alterations in tooth number, shape and size. The morphogenesis of the lower incisor in Ta mice has been described based on 3D reconstructions during embryonic days (ED) 13.5-18.0. We expanded this previous study and investigated the temporo-spatial dynamics of Shh expression in the developing dental epithelium in the lower incisor region of finely staged Ta embryos at ED12.5–15.5. The Shh expression, recognized as a marker of early tooth development, was visualized by whole mount in situ hybridization and compared in the mandibles of Ta and wild-type embryos matched according to similar age and body weight. We found no marked differences in Shh expression in the incisor area between Ta and wild-type mice on ED12.5 or 13.5 (body weight till 130mg). However, from ED13.5 (body weight 140mg) onwards, the Shh expression was much less intense and smaller in size, although its localization was similar to that seen in wild-type embryo. Interestingly, the Shh expression pattern until ED13.5, which corresponds to the development of the rudimentary incisors, was not altered in Ta embryos. This suggests that the development of the rudimentary incisors is not impaired in Ta mutants. In contrast, the observed decrease in Shh expression in Ta mandibles from ED13.5 onwards corresponded to the stage when the lower functional incisor germ forms. This result correlates with the previous morphological data showing hypoplasia of the functional incisor primordium in Ta mice from ED13.5.

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Evolution of hypercarnivorous dentitions in mammals

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Most mammals with dominant carnivorous diet possess mixed cutting and grinding dentitions including secodont carnassial teeth. Carnassial cheek teeth are mesio-distally elongated, transversally compressed, and sharp edged teeth adapted to carve meat. The number of carnassial teeth varies from one per quadrant in Carnivora to four in carnivorous Marsupials. An evolutionary trend towards hypercarnivory independently occurred several times among Metatheria (Sparassodonta, Dasyuromorphia) and Eutheria (Creodonta, Carnivora). Hypercarnivorous mammals only keep secant cheek teeth and their orthal jaw movements exclusively produce a slicing action similar to the way scissors cut through paper. Acquisition of hypercarnivory involves important simplifications of cheek teeth, such as cusp reduction, fusion or loss. The loss of numerous dental structures and the modification of the overall tooth shape raise questions concerning developmental mechanisms controlling these convergent evolutions.

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The topography and morphology of the mandibular canal of skulls from two historical populations.

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Some studies suggest that mental foramen and mandibular canal may show some geographic as well as historical variation. The non-metric traits can differ in various ethnic populations and can be used as an indicator of human homeostasis. The aim of this study was to analyse the topography and morphology of the mandibular canal of skulls from two historical populations and to estimate the changes occurring through the centuries. The material consisted of two groups: contemporary and medieval skulls originating from Pomerania region of Poland. Direct measurements were taken on the skulls and the measuremnts on a x-ray photos. The statistical analysis was performed using the Statistica for Windows computer software package. Significant differences were observed in the topography of the mandibular canal in both groups. Distance from the base to the bottom of the mandibular canal was higher in the contemporary group than in a skulls from Middle Ages. However, the distance from the roof of the mandibular canal to the alveolar ridge of the mandible was greater in the medieval mandibles. These mandibles were also characterized by larger dimensions of the bodies. Significant asymmetries of mandibular canals were found in both groups.

Dietary Adaptations of the Earliest Anthropoids

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Dental morphology of extant small-bodied primates was compared between primarily insectivorous species (*Tarsius bancanus*, *Loris tarigradus*, *Arctocebus calabarensis*, *Galago senegalensis*, *Galagoides demidovii*) with more frugivorous/gumnivorous forms (*Cheirogaleus medius*, *Microcebus murinus*, *Phaner furcifer*, and *Euoticus elegantulus*). First and second lower molars were scanned with a Laser Design Surveyor RPS-120 probe laser scanner. Scans were made with a step size of 0.01mm and each specimen was scanned from 6 different angles for complete tooth coverage. Geomagic was then used to merge, clean, and decimate the scans into a single completed model before being exported into SurferManipulator for analysis. All teeth were scaled to the same length of 150 data rows and topographic contour maps were created. Orientation path count (OPC) was calculated as any time 2 or more patches had the same slope orientation (within a range of 8 possible predefined orientations). Results indicated that more traditional measures (e.g. shearing crest length) appear to be better indicators of diet within tight taxonomic units with quantifiable homologous dental features, whereas OPC counts are more robust across more distantly related taxa. Nine species of small-bodied middle-late Eocene primates were compared to this extant sample. Results indicate that *Eosimias centennicus*, *E. sinensis*, and *Xanthorhysis tabrumi* were the most insectivorous whereas *Arsinoea kallimos*, *Catopithecus browni*, *Plesiopithecus teras*, *Proteopithecus sylviae*, *Qatrani wingi*, and *Serapia eocaenus* were more similar to living frugivorous primates. These results indicate that primitive African anthropoids were ecologically distinct from insectivorous eosimiids and that the initial radiation of Anthropoidea involved diversification of feeding strategies.

Expression of Carabelli`s trait on deciduous molars in Croatian late antique and medieval populations

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Carabelli`s trait (CT) is one of the most intensively studied dental morphological traits. Majority of published studies are performed on permanent teeth. Studies of expression of CT on deciduous teeth are very rare especially if performed on archaeological samples. Respecting that deciduous molars are morphologically considered a model for the permanent molars (isomorphy), examining deciduous molars it is possible to get data on crown patterns of permanent molars in an indirect way. This is very important in bioarchaeological investigations where the possibilities of crown patterns study are limited by excessive tooth wear. The purpose of this study was to examine the incidence and degree of expression of a CT on deciduous molars in samples from late antique - LA (3rd – 6th century) and medieval - M (7th – 11th century). Research has been carried out on 68 subadult Caucasian skulls (12 LA and 56 M) with 130 intact deciduous maxillary second molars excavated at 6 archaeological sites in Croatia. Expression of CT was classified according to the 8 level Dahlberg's scale. CT was identified on 41.67% of examined teeth in LA sample and on 50.00% in M sample. Frequency of tubercle and cusp forms only was in LA sample 25.00% and 8.92% in M sample. There were no statistically significant differences in frequencies. According to the frequencies of CT both samples belong to the Garn`s intermediate frequency group. Deciduous molars of archaeological samples are often intact and should be used as substitute if permanent molars are unavailable for examination.

Fossil and archaeological tooth preparation for histological analysis

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Teeth, whether they are fossilized or modern all have to be sectioned in a similar fashion with similar machinery and similar methods. Whether you are looking for differences between species, growth processes and patterns or cusp thickness whatever the research program requests all require that the teeth be ground down to a section of approximately 70um to approx 100um. Machinery used in the preparation of ground sections within the Hard Tissue Laboratory of the School of Dental Sciences, Newcastle University, are a Microslice saw with a circular diamond edged blade measuring 250 microns and a PM2A precision lapping and polishing machine using varying grades of calcined aluminium oxide powder for grinding down the cut sections. The cut sections are bonded using Logitech UV resin also methacrylate. Using various dilutions of alcohol when mounting the sections progressing to Histo-Clear II, it is necessary then to attach the cover slips using Histomount, which has a refractive index matched to cover slips and slides. In the preparation of ground sections for fossil and archaeological teeth, there are a few extra steps to be taken first to ensure the complete documentation of the specimen:

- Written data
- Photographing the specimen
- Radiographs if required
- Replicating for the museum to which the specimen belongs
- High resolution Spurr resin casts if required for S.E.M. analysis
- Embedding of fragile fossil and archaeological teeth before sectioning

The results of ground section preparation whether with modern teeth or fossilized, should be consistent.

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How accurately can age be estimated from eruption status?

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The aim of this study was to assess methods age estimation from radiographic stages of tooth eruption. The test-sample was dental panoramic radiographs of 946 children aged 3-16 years. Age was estimated for individuals with permanent mandibular teeth at the alveolar bone level or midway to the occlusal level. The difference between estimated age and real age was compared to zero using a t-test. Methods assessed were Haavikko (1970) stages alveolar eruption and midway to occlusal level and Ando et al. (1965) alveolar eruption and Garn et al. (1958) alveolar eruption of premolars and molars for 483, 311 and 260 individuals respectively. Results show that the average difference between estimated age and real age using Ando et al. was not significant to zero, while on average, Haavikko significantly under-estimated age and Garn et al. over-estimated age. Results for individual teeth show that the difference between estimated and known age was not significantly different to zero for Ando et al. using the first molar (ages 4 to 7) and both premolars using Garn et al. (ages 8 to 14). The 95% confidence interval (CI) of estimated age using all erupting teeth using Ando was $\pm$ 2.5 years and for premolars using Garn was $\pm$ 2.7 years. This was considerably greater than the 95% CI of estimated age using tooth formation on the same individuals [$\pm$ 1.5 years]. These results show that teeth at alveolar eruption can estimate age, but tooth stage assessment provides a more reliable estimate.

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Changes in mammalian dental complexity following the Cretaceous-Paleogene mass extinction with implications for ecological recovery and expansion

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Following the Cretaceous-Paleogene (K-Pg) mass extinction and associated collapse of dinosaur-dominated terrestrial ecosystems, an early Paleocene biotic recovery ensued that transitioned into an unrivaled evolutionary radiation of mammals. Studies of this critical transition, particularly those with a quantitative ecomorphological perspective, are fundamental to understanding the complexity of evolutionary and ecological dynamics, but are currently lacking. Most studies on the post K-Pg recovery and radiation of mammals have focused on taxonomic diversity. We measured changes in 3D dental morphological diversity of mammalian faunas (orientation patch count [OPC] of molar rows) across the K-Pg boundary in northeastern Montana. Dental morphological disparity changed very little across the K-Pg boundary despite major faunal turnover via extinction, speciation, and immigration. Latest Cretaceous mammalian faunas, composed of multituberculates, metatherians, and rare eutherians, have an OPC range that corresponds to values found among faunivores, animal-dominated omnivores, plant-dominated omnivores, and herbivores in extant rodents and carnivorans. Earliest Paleocene mammalian faunas, composed of multituberculates and eutherians and one metatherian species, have a similar OPC range but a greater proportion of plant-dominated omnivores and herbivores than the latest Cretaceous fauna. Relative abundance data, however, imply that these plant-eating taxa, many of which immigrated into the region, were a minor component of the survival fauna. The results suggest that despite major upheaval to the mammalian fauna, many feeding ecologies present in the latest Cretaceous that were vacated during the K-Pg extinction event were replaced through immigration and in situ evolution within the first 200 thousand years of the Paleocene.

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A fluorochrome labelling study to determine enamel and dentine extension and apposition rates in molars of Soay sheep

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Teeth of domestic sheep are frequently represented in the archaeological record. A detailed knowledge of the chronology of tooth development in the species is vital for age-at-death determination and life-history reconstruction. To obtain data on the timing of crown formation in molar teeth of sheep, we conducted a vital labelling study in Soay sheep (n=9) with injections of tetracycline and calcein that were given at regular-intervals (total of between 5 and 20 injections per individual). Axiobuccolingual ground sections of mandibular molars were then examined with a fluorescence microscope, and enamel and dentine extension and apposition rates were determined. Injection of tetracycline caused a reduction in enamel and dentine apposition rates when compared with calcein injection. In addition, tetracycline application caused the formation of a structurally altered incremental line in the enamel. Determining the distances between successive fluorochrome labels at the enamel-dentine junction revealed a marked reduction in enamel and dentine extension rates in cervical direction, indicative of a decreasing number of cells starting secretory activity. Enamel apposition rate, denoting secretory activity of the ameloblasts, markedly increased from the inner to the outer enamel. In primary dentine, the variation in apposition rate between early and later formed dentine was less pronounced. In the enamel, incremental markings with a daily periodicity were recorded. These markings exhibited characteristics resembling those previously reported for long period incremental markings (i.e. striae of Retzius) in primate enamel. In addition, also incremental markings with a shorter (infradian) periodicity were recorded in the sheep enamel.

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Paranthropus boisei in the role of model organism: revisiting _Paranthropus_ monophyly through the inhibitory cascade model of postcanine development.

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Model organisms are studied extensively in order to understand biological phenomena. Among the most unusual teeth in mammalian evolutionary history are the relatively and absolutely large postcanines of the early hominin *Paranthropus boisei*. The high degree of molar hypertrophy and molarization of the mandibular premolars in *Paranthropus* has been argued to be a synapomorphy of this clade but may be the product of homoplasy. Evolutionary developmental models provide predictive frameworks for understanding the origins of adaptive morphologies such as molarization. The inhibitory cascade model of molar development is here applied to the M1-M3 and P3-M1 sequence in *Paranthropus* taxa in order to evaluate whether molar hypertrophy and molarization in these species follows the same developmental pattern. Total crown areas of *Paranthropus* maxillary and mandibular postcanines were collected from precision casts and from the literature. Analysis of the molar row demonstrates similar developmental patterning in both *P. robustus* and *P. boisei,* with the morphology of *Paranthropus* molars representing an “extreme” form of the pattern seen in early hominins. Analysis of the P3-M1 sequences suggests their developmental origin may not the same in the two taxa. Specifically, the pattern of P3-M1 development in *P. boisei* resembles that of the molar sequence. This application of the inhibitory cascade model suggests that developmental frameworks have potential for evaluating hypotheses generated to explain evolutionary relationships.

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The type and frequency of non-carious cervical lesions in the present-day Japanese

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Non-carious cervical lesions (NCCLs) are characterized by the loss of hard tissue at the cement-enamel junction (CEJ) in the absence of caries. Various forms of NCCLs had been observed in former studies. However, the frequency of each form had not been investigated. It is generally accepted that initiation and progression of NCCLs have a multi-factorial etiology. The most widely accepted causes of NCCLs are abfraction and abrasion, while other mechanisms such as erosion and corrosion have also been proposed. The aim of this study is to classify the morphology of NCCLs, to investigate the frequency of each form, and to consider their causes. We macroscopically observed 4000 extracted permanent teeth of the present-day Japanese under illumination at 10× magnification. NCCLs were classified by the combinations of the contour on the surface and the cross-sectional shape. NCCLs were most frequently found in the canine and the first premolar. The frequencies of NCCLs were high on the labial side in almost all type of teeth. At the same time, NCCLs were frequently observed also on the lingual side in the posterior and anterior teeth. Some forms were recognized characteristically in particular teeth. In the canine, the type of the "crescent" (contour on the surface) and "circle"(cross-sectional shape) was most frequently observed. In the premolars, the frequency of "wedge"(cross-sectional shape) was the highest. The morphologies of NCCLs have proved to be different among the types of teeth, which suggests that causes of NCCLs were different in the types of teeth.

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Variation in the development of the primary dental enamel in the infant remains from the archaeological samples of Neolithic and Mediaeval human populations from the Polish Lowland

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The aim of this study was to determine the variation in the primary dental enamel development in human populations living in Poland in the early Neolithic and Mediaeval times. The material consisted of 75 deciduous incisors obtained from 34 subadult skeletons from two historical samples (10 skeletons from the Neolithic population dating to 4300-4000 B.C. and 24 skeletons from two Mediaeval series dating to 12th-16th century). A total of 75 maxillary primary central incisors were investigated using light microscopy and scanning electron microscopy (SEM). The longitudinal section of each tooth was examined, and maximum dimensions of the prenatally and postnatally formed enamel, and the maximum width of the neonatal line were measured. Comparative material included deciduous teeth obtained from the skeletal sample dating to the modern times (18th-19th century) and from the contemporary living children. All parameters of the primary dental enamel: pre- and postnatal enamel width, and the NNL width were statistically different (ANOVA $P<0.05$) between compared populations. The NNL of the Neolithic teeth was over 1.5 times greater than that for Mediaeval teeth and over 2 times greater than that for contemporary teeth. In teeth from Neolithic population the prenatal enamel layer was over 53% wider than the enamel formed after birth (in the Mediaeval teeth the difference exceeds 29% whereas in the contemporary teeth the difference exceeds 23%). This preliminary report suggests that the primary dental enamel in Neolithic populations was characterized by the slower rate of development.

Inner structural morphology and perinatal development of two Javanese *Homo erectus* deciduous teeth

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In the human dentition, the transition from an intra- to extra-uterine environment leaves its mark in all deciduous teeth (and the M1 mesial cusp) in the form of an accentuated enamel incremental ring. This "neonatal line" (NL) is observable in individuals who survive 7 to 10-15 days after birth. Besides the dynamics of leaving the womb, its appearance relates to a drop in serum calcium values during the first 48-72 hours *ex utero*. Analysis of the NL, whose location is specific to each tooth class, is routine in forensic investigations, increasingly prevalent in studies of archaeological population samples, but rare in fossil taxa. The NL has been recognized in some Neanderthal and early anatomically modern human deciduous teeth, but its expression is unreported in *Homo erectus*.Here we present the comparative results from the high-resolution record realized at the SYRMEP beamline Elettra of Trieste, Italy (6.25 µm resolution) and the Centre de Microtomographie of the University of Poitiers, France (21.64 µm resolution) on two human deciduous molar crowns from the late Early-Middle Pleistocene Kabuh formation outcropping near the village of Pucung, in the southern part of Sangiran (Central Java, Indonesia), a fossiliferous area having yielded numerous odontoskeletal remains attributed to *H. erectus s.s.*, including over 200 dental elements. These nearly unworn specimens represent an upper left m1 (Ulm1) and a lower left m2 (LLm2). We have characterized the two crowns in terms of tissue proportions, enamel thickness variation, enamel-dentine junction topography, and NL outline and relative position (and, tentatively, thickness).

Analysis of enamel thickness and distribution patterns in the dentition of *Gigantopithecus blacki*, Early Pleistocene from Guizhou in Southwest China

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Enamel thickness and distribution patterns play an important role in the study of functional demand and dietary proclivity of *Gigantopithecus blacki*. Researchers have been mainly focused on the thick enamel of molars of *G. blacki.* By means of a non-destructive micro-CT based methodology, we investigated enamel thickness features of five teeth of different tooth types of *G. blacki*: two incisors, one canine, one premolar and one molar, with minor attrition and breakage, which were discovered recently in an Early Pleistocene fossil site in Bijie, Guizhou Province in South China. Two indices of enamel thickness, three-dimensional average enamel thickness (3DAET) and three-dimensional relative enamel thickness (3DRET), were calculated for each tooth. Moreover, another two indices, two-dimensional average enamel thickness (2DAET) and two-dimensional relative enamel thickness (2DRET), were also calculated through the mesial cusps in the molar sample. The results of 3DAET and 2DAET in molar show that *G. blacki* has the thickest enamel thickness when compared with *Lufengpithecus*, Chinese Pleistocene *Pongo* and other extant and extinct primates. The data from 2DRET, however, overlap with that of *Lufengpithecus* and Chinese Pleistocene *Pongo* respectively. In each tooth type, the results of enamel thickness also indicate the character of enamel distribution, which is closely related to functional demand. Besides molars, the dietary inferences about *Gigantopithecus blacki* are interpreted in view of the incisor, canine and premolar.

Mineralization of oral tissues; the role of calcium

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Previous studies have confirmed that Vitamin D, which regulates intestinal calcium absorption and renal calcium resorption, is involved in the mineralization process. The oral environment offers a unique opportunity to study the development of several distinct mineralized tissues. In order to further understand the mineralization process in these tissues and the role of calcium in their development, we have utilized a mouse model with a genetically engineered vitamin D receptor deficiency to study the mineralization patterns of enamel, dentin, cementum, and alveolar bone, by a variety of experimental methods. Our ongoing studies using this mutant have shown that enamel develops earlier in mutants and was hypermineralized. This early enamel mineralization was not associated with delayed eruption of the incisors. In contrast, dentin was hypomineralized, showed sporadic porosity and was thinner. Cementum deposition on all molar teeth displayed minimal apposition, with subsequent open apices and alveolar bone was hypomineralized and osteoporosis-like. Systemic supplementation of mutant animals with calcium had little effect on enamel. However, dentin and alveolar bone showed increased mineralization density and thickness, while cementum was rescued to the normal mineralization levels. We conclude that differential mineralization patterns exist in enamel, dentin, cementum and alveolar bone. Enamel appears to be regulated by vitamin D locally; both local and systemic mechanisms appear to function in the dentin and alveolar bone, while cementum is mainly influenced by systemic calcium levels.

Dental development and enamel thickness of *Lufengpithecus* from Lufeng site in Southwest China

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Using SEM and nondestructive microtomographic and physical histological methods, information on dental development and enamel thickness were collected on the Late Miocene *Lufengpithecus lufengpithecus* from the Lufeng site in Southwest China. Preliminary analysis shows the following results:

1) The periodicity of Retzus lines (at least 9 teeth, probably belonging to different individuals) is 9 days in *Lufengpithecus lufengpithecus*, which is similar to that of Pleistocene *Pongo* or *Pongo*-like teeth from south China, and is shorter than that of *Gigantopithecus*, but is longer than that of most of fossil and extant primates.
2) The crown formation times of anterior teeth, incisors and canines, estimated by counting the perikymata, are relatively long, when compared to other extant and extinct hominoids.
3) The lateral enamel formation time of the molar of *Lufengpithecus lufengpithecus* estimated by counting Retzius lines, is somewhat shorter than that of Pleistocene *Pongo* from South China.
4) The proportion index of molar cusp/ lateral enamel formation time is larger in *Lufengpithecus lufengpithecus* than in Pleistocene *Pongo*.
5) The two-dimensional relative enamel thickness of molar indicates the thick-enamel characteristic in *Lufengpithecus lufengensis*.
6) The relative enamel thickness of molars is significantly variable within *Lufengpithecus lufengpithecus*, which might be interpreted by intraspecific variation, sexual dimorphism or different taxa in the sample.

The results show that the features of enamel development and thickness of *Lufengpitheus lufengensis* are very important and helpful for us to understand the issues of life history evolution, adaptation, taxonomy and phylogeny of *Lufengpithecus* and other associated hominoids in East Asia.