Neuroscience and Biobehavioral Reviews 163 (2024) 105745

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Reading children's teeth to reconstruct life history and the evolution of human cooperation and cognition: The role of dental enamel microstructure and chemistry

Alessia Nava [a,*], Federico Lugli [b,c,d], Simone Lemmers [e,f,g], Paola Cerrito [h], Patrick Mahoney [i], Luca Bondioli [j], Wolfgang Müller [b,c]

[a] Department of Odontostomatological and Maxillofacial Sciences, Sapienza University of Rome, via Caserta 6, Rome 00161, Italy
[b] Institut of Geosciences, Goethe University Frankfurt, 60438, Frankfurt, Frankfurt am Main, Germany
[c] Frankfurt Isotope and Element Research Center (FIERCE), Goethe University Frankfurt, Frankfurt am Main, Germany
[d] Department of Chemical and Geological Science, University of Modena and Reggio Emilia, via Giuseppe Campi, 103, Modena 41125, Italy
[e] Elettra Sincrotrone Trieste S.C.p.A., AREA Science Park, s.s. 14 km 163,500, Basovizza, Trieste, Italy
[f] Department of Psychiatry, Harvard Medical School, 401 Park Drive, Boston, MA, USA
[g] Center for Genomic Medicine, Massachusetts General Hospital, 185 Cambridge Street, Boston, MA, USA
[h] Department of Evolutionary Anthropology, University of Zürich, Zürich, Switzerland
[i] School of Anthropology and Conservation, University of Kent, Giles Ln, Giles Ln, Canterbury CT2 7NZ, UK
[j] Department of Cultural Heritage, University of Padua, Piazza Capitaniato, 7, Padua 35139, Italy

ARTICLE INFO

Keywords:
Histomorphometry
Laser-based biogeochemistry
Mother-infant dyad
Dietary patterns
Mobility

ABSTRACT

Studying infants in the past is crucial for understanding the evolution of human life history and the evolution of cooperation, cognition, and communication. An infant's growth, health, and mortality can provide information about the dynamics and structure of a population, their cultural practices, and the adaptive capacity of a community. Skeletal remains provide one way of accessing this information for humans recovered prior to the historical periods. Teeth in particular, are retrospective archives of information that can be accessed through morphological, micromorphological, and biogeochemical methods. This review discusses how the microanatomy and formation of teeth, and particularly enamel, serve as archives of somatic growth, stress, and the environment. Examining their role in the broader context of human evolution, we discuss dental biogeochemistry and emphasize how the incremental growth of tooth microstructure facilitates the reconstruction of temporal data related to health, diet, mobility, and stress in past societies. The review concludes by considering tooth microstructure as a biomarker and the potential clinical applications.

1. Introduction

The period encompassing intra-uterine life and early childhood, extending post-conception to approximately 1000 days constitutes a pivotal phase in an individual's development. This developmental period significantly shapes our adult life trajectory, impacting facets of our health, susceptibility to specific diseases, longevity, and socio-cognitive abilities (Barker, 2001, 2004; Burkart and Van Schaik, 2010; Juster et al., 2011; Lupien et al., 2009; McEwen, 2012). Beyond factors inherent to pregnancy, such as maternal well-being, health, and nutrition, early childhood is profoundly shaped by an individual's social identity, cooperative caregiving, community dynamics, and environmental influences (Fig. 1). Living conditions throughout intra-uterine life and during growth are reflected in frailty and mortality in adulthood, as well as in susceptibility to mental illnesses (McEwen, 2003). Consequently, early childhood and its subphases are commonly denoted as 'sensitive periods' (Knudsen, 2004).

In recent years there has been increased attention, from a medical and social perspective, on the importance of the earliest moments of an individual life (Brüne and Schiefenhövel, 2019; Kendall et al., 2020). This has cascaded into historical and evolutionary reconstructions of the mother-infant (and alloparent – infant) dyad and how this relationship has changed through time and between cultures (Gowland and Halcrow, 2019; Halcrow et al., 2020; Martin et al., 2020; Miller et al., 2020; Nava,

* Corresponding author.
E-mail address: alessia.nava@uniroma1.it (A. Nava).

https://doi.org/10.1016/j.neubiorev.2024.105745
Received 9 February 2024; Received in revised form 25 May 2024; Accepted 30 May 2024
Available online 31 May 2024

2024; Page et al., 2019; Rebay-Salisbury and Pany-Kucera, 2020; Stefanović et al. 2019). Understanding the life histories of infants in the past is critical for understanding how humans and their societies have evolved.

Human life history is characterized by unusually short inter-birth intervals and early weaning (Nava et al., 2020; Robson and Wood, 2008). Hence, from a very young age, human children can be typically cared for by multiple caregivers (alloparents) in addition to the mother – making the evolution of our life history linked to that of our cooperative breeding behaviors and associated socio-cognitive and communicative abilities (Van Schaik and Burkart, 2010). Indeed, human development occurs within a social environment rich in interpersonal relationships, such as those with parents, siblings, and extended family members. This setting provides the backdrop for the emergence of strong social cognition and prosocial behaviors in young children (Hrdy and Burkart, 2020). During this crucial period, neural networks underlying advanced social, emotional, and communicative skills are established (Courchesne et al., 2007; Grossmann and Johnson, 2007; Hawkes and Finlay, 2018; Leppänen and Nelson, 2009). Multiple disciplines, including neuroscience, primatology, and psychiatry, converge to emphasize the critical temporal interplay between brain maturation and social experiences in shaping social cognition and prosocial tendencies (Grossmann and Johnson, 2007). In sum, reconstructing the evolutionary history of the unusually early age at weaning and characteristically short interbirth intervals of humans (Kuzawa and Bragg, 2012), means reconstructing the adaptations of our reproductive strategy that have led human infants to be exposed to a plurality of interactions during early brain ontogeny which have been shown to "tune" the social brain (Hawkes and Finlay, 2018).

Investigating individual life trajectories allows us to grasp the interplay between societies and their societal and ecological milieu (Fig. 1) (Agarwal, 2016; Halcrow, 2020). Many aspects of reproduction, child-rearing, care, and socialisation are central to archaeological and anthropological questions about the organisation of past societies, including division of labour, mobility, resource scheduling, and birth spacing (Baxter, 2022; Gowland, 2015). The study of infant growth, health and mortality is therefore essential in teasing apart lived experiences of health and disease in the past, including insights into infant feeding practices, fertility, family and social structure, population size (Gowland, 2015; Halcrow, 2020) and the adaptive capacity of a community (Kubat et al., 2023; Nava et al., 2020).

The study of human remains from archaeological contexts is known as human bioarchaeology. Human skeletal and dental remains are an excellent archive from which to study the human past. Teeth are often the most direct route for gaining insights into the lives of our ancestors (de Vareilles et al., 2021; Hardy, 2010; Zohar et al., 2022). Moreover, studies of dental and skeletal remains enable reconstructions of population dynamics. However, human skeletal remains rarely represent a true cross-section sample of a living society at a given time, because large-scale skeletal assemblages predominantly originate from funerary contexts. Indeed, the funerary record represents those who perished rather than those who were alive, which has been referred to as the Osteological Paradox (DeWitte and Stojanowski, 2015; Wood et al., 1992). The analyses of teeth provide one way of overcoming this limitation because they retain a longitudinal record of their formation.

Traditionally, human bioarchaeology has focused more on the adult segment of ancient populations, while studies of subadults have attracted less attention (Bondioli et al., 2016, 2020; Kamp, 2001). Less is

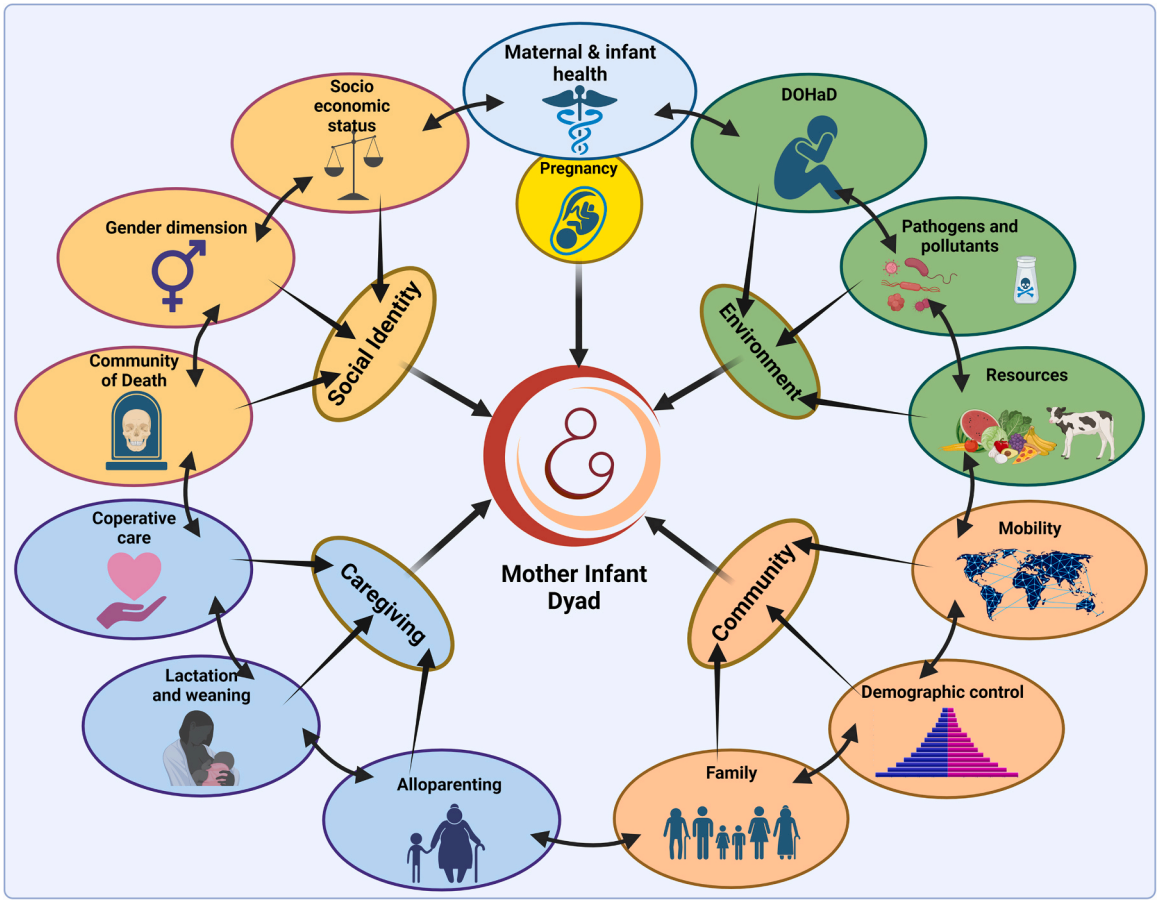

Fig. 1. The mother-infant nexus and bioarchaeology model of infancy and childcare (adapted from Halcrow et al. 2020). DOHaD = Developmental Origin of Health and Disease hypothesis.

known about child development, nutrition and their place in past societies, which is partly due to the scarcity of archaeological and historical records (Bondioli et al., 2020; Kamp, 2001). However, in recent years, attention has started to shift and the field is gradually becoming more focused towards infants and subadults in the past (e.g. Halcrow, 2020; Halcrow et al., 2020). These studies have started to address the role childhood development can play in the reconstruction of past population dynamics and social organization. Studies of teeth, both deciduous and permanent, are central to this developing aspect of human bioarchaeology.

2. Reconstructing life in the past from teeth

Teeth are of particular interest to bioarchaeologists because they can provide insights into the health, stress and mortality of subadults in past societies (e.g. FitzGerald et al., 2006; Kierdorf et al., 2021; Lorentz et al., 2019; Nava et al., 2017a; Sipovac et al., 2023). Teeth are the most durable of human remains and preserve well after death. They are a rich source of human life history (Stearns and Rodrigues, 2020), its evolution, as well as individual life stories that can be accessed through micromorphological (histological) and biogeochemical methods (e.g. Austin et al., 2023; Fleming, 2009; Montgomery, 2010; Müller et al. under revision; Nava et al., 2020; Smith et al., 2021). Although all dental tissues (i.e. enamel, dentine and cementum) can preserve valuable information about an individual's biology, our review focuses on dental enamel. Indeed, tooth enamel microstructure becomes visible from the second trimester and continues to form until early adolescence. Unlike bone, enamel does not remodel once formed (Hillson, 2023). Therefore, a single tooth crown can capture a specific period of a child's development, and in this sense, teeth can be thought of as 'time capsules'. Forming enamel retains signatures of physiological growth, nutrition, and disruptions to an individual's homeostasis. As such, researchers are able to access these aspects of a child's life and recreate longitudinal records rather than reconstructing just a single point in time. This means that investigations of teeth can provide a way of partially overcoming many of the limitations that are typically inherent in mortality sample studies. Furthermore, the appositional growth process that governs tooth enamel formation preserves a time-resolved signal of such events (Dean, 2006). If extracted at sufficiently high spatial resolution, this process allows for daily to weekly temporal resolution. Therefore, the

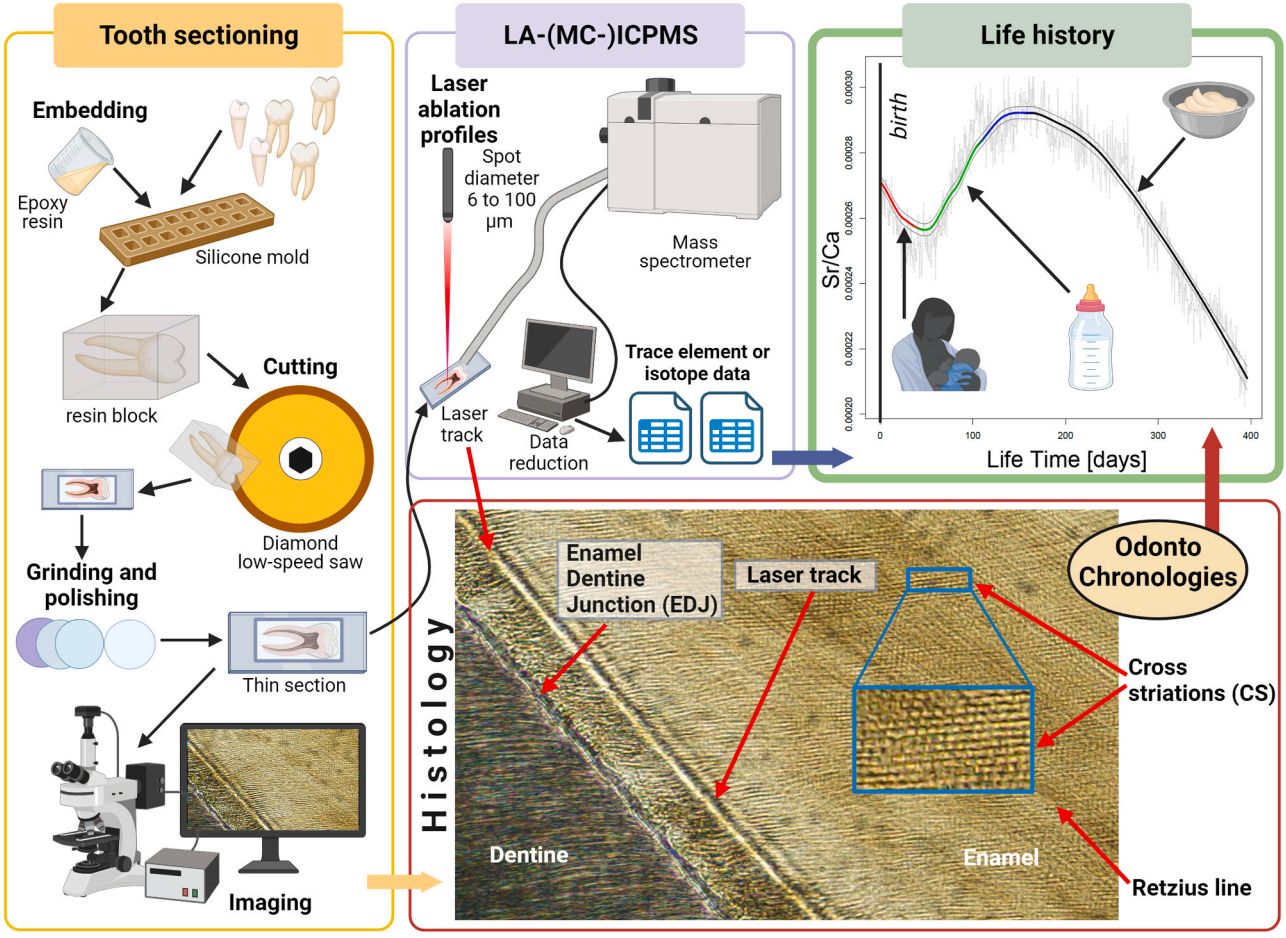

Fig. 2. Schematic representation of the analytical workflow for the reconstruction of individual life histories from dental histology coupled with spatially-resolved laser-based biogeochemical analysis. The workflow foresees the tooth sectioning (yellow box). After photographic documentation, the tooth is sectioned using a standard histological protocol (Nava et al. 2019). The tooth is first embedded in epoxy resin to prevent fractures during sectioning. Is then sectioned using a low-speed diamond blade saw. After the first cut, a microscope slide is attached to the exposed surface using the epoxy resin and a single longitudinal bucco-lingual thin section is cut from the specimen. Each thin section is then reduced to the appropriate thickness (~150 µm) using water-resistant abrasive paper and polished with a micro-tissue and diamond paste. The thin section is digitally recorded with a high-resolution digital camera paired with a transmitted light microscope to assemble the single frames into a photomosaic of the entire crown. The photomosaic is analysed to retrieve dental growth parameters (red box, see later in the main text and caption Fig. 3). The same thin section is subjected to biogeochemical analysis using a laser ablation instrument coupled to an ICPMS or an MC-ICPMS to measure elemental ratios (Müller et al. 2019) and isotope ratios (Lugli et al. 2022b; Müller and Anczkiewicz, 2016) respectively (purple box). The determination of odontochronologies along the laser track allows for the reconstruction of the individual life history during the period of tooth formation, for example, the reconstruction of the early life dietary history (green box).

microscopic and high-resolution biogeochemical analyses of tooth enamel properties are emerging as potent tools for obtaining highly detailed information about specific life histories (e.g. Dean et al., 2019; Joannes-Boyau et al., 2019; Kubat et al., 2023; Li et al., 2022; Müller et al., 2019; Nava et al., 2020; Smith et al., 2018a)(Fig. 2).

By harnessing the temporal growth of dental microstructures alongside their remarkable durability, researchers have started to achieve unprecedented advancements in the exploration of childhood also in the past (Aris et al., 2020; Austin et al., 2013; Dean, 2016, 2017; Dean and Cole, 2013; Dean and Elamin, 2014; Dean and Liversidge, 2015; Dean et al., 2019; Joannes-Boyau et al., 2019; Kubat et al., 2023; Mahoney et al., 2022; Mahoney et al., 2021; Nava et al., 2017a; Nava et al., 2020; Rosas et al., 2017; Smith et al., 2018a; Smith et al., 2021). These methodological strides, coupled with the introduction of novel interpretative frameworks, contribute to a more profound understanding of the intricate interplay among subadult health, parental care, mortality, and morbidity. **Here, we discuss the current methodological advancements for investigating sub-adult life histories from teeth, with a specific focus on infancy and childhood. We also consider the challenges within the subject and the new opportunities and technological developments that are currently underway.**

1) First, we discuss the fundamentals of dental growth and tooth microanatomy. The way that dental tissue is deposited is crucial to understanding the type of information that teeth can contain, how the information is preserved and how it can extracted.
2) Next, we discuss how teeth reflect and preserve somatic growth and its role in the deeper context of human evolution, and how such information is extracted using measurements and calculations of dental microstructure.
3) We then proceed to discuss dental biogeochemistry and how the incremental deposition of tooth microstructure allows us to reconstruct high-temporal resolution individual life history data in relation to health, diet, mobility and stress signatures.
4) Finally, we conclude by outlining how such intricate details about teeth and human life history can help us to understand the evolution of uniquely human socio-cognitive abilities, modern human variation, the interaction cross-overs archaeological studies of dental remains can have with modern medical approaches and hinting towards future approaches for the field.

3. A schematic overview of dental development and microanatomy

Tooth growth in humans is influenced by individual biological rhythms that are expressed in the microstructures of enamel, dentine and cementum (Boyde, 1989). The appositional formation of teeth makes it possible to relate growth, stress and biochemical aspects of development to a chronology.

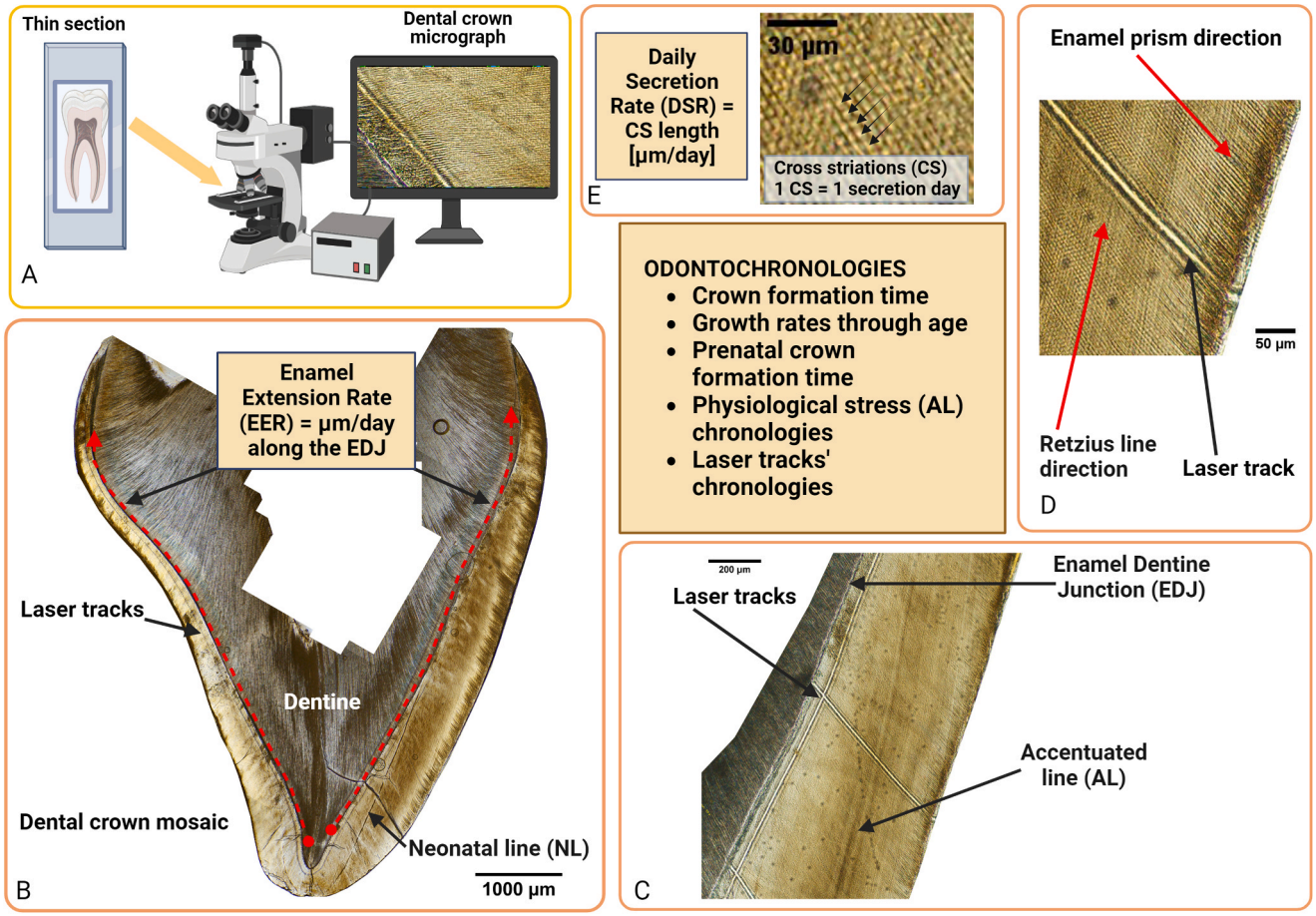

Fig. 3. Schematic overview of dental enamel microstructures and developmental parameters. A) Optical microscopy analysis of a dental thin section used to produce the photomosaics of the entire dental crown. B) Photomosaic of the thin section of a human deciduous upper canine crown. The black arrow points at the neonatal line, the birth marker. The red dotted lines highlight the direction of the enamel extension, i.e. the crown growth in height, from which EER is calculated as the rate of differentiation of secretory ameloblasts recruited along the enamel-dentine junction. C) Portion of the same photomosaic in B highlighting the laser tracks after LA-ICPMS analysis, the enamel dentine junction, and an accentuated stress line (AL). D) Further magnification of the photomosaic in B and C showing the enamel prisms and Retzius lines directions and the laser track.

Dental enamel, which is our focus here, starts developing in utero (at the beginning of the second trimester of pregnancy) forming the primary, deciduous dentition (Nanci, 2007). Around birth, all of the deciduous teeth, and a small portion of the first permanent molar, have usually commenced formation. The permanent teeth then continue to form sequentially until adolescence. Therefore, the study of dental enamel structure and chemistry can relate to an individual's life history roughly between late pregnancy and about 15 years of age.

The study of enamel growth dates back to the earliest moments of microscopy (Leeuwenhoek, 1677). The early part of the 20th century saw the first use of enamel incremental structures to reconstruct the chronology of tooth crown formation in clinical dentistry by Kajiyama (1965), Schour and Massler (1940), Tagiguchi (1966). However, Schour (1936) was the first to fully describe a marker of birth in teeth (see later in the text and Fig. 3B) and Boyde (1963) was the first to use enamel incremental markings to establish an age at death in archaeological material. The history of these early studies has been fully reviewed by Boyde (1964), Dean (1987), FitzGerald (1998), Smith (2006), and most comprehensively by Hillson (2023).

Markers of biological rhythms essentially follow two different time series with different frequencies. The first has a daily rhythm that relates to the day-night alternation (Zheng et al., 2014, 2013). The daily rhythm is expressed in enamel microstructure as cross striations that are visible along enamel prisms (Antoine et al., 2009; Bromage, 1991; Lacruz et al., 2012) (Fig. 3 D, E). The second rhythm in humans is characterized by a circaseptan (nearly weekly) periodicity, probably related to oscillations of biological rhythms over a longer period that are specific to each individual (Mahoney et al., 2022, 2018, 2017, 2016). These longer period rhythms appear to change between the anterior and posterior dentition of a single individual, at least for some individuals (McFarlane et al., 2020). The long-period rhythm becomes visible microscopically on dental thin sections as brown striae that are known as Retzius lines (Fig. 3, C) (Dean, 2019; FitzGerald, 1998; Retzius, 1837). Retzius lines demarcate 'layers' that emerge on the outer surface of the dental crown, where they are expressed as perikymata (Nanci, 2007).

There are other types of marking that occur in enamel, but these typically do not have a consistent rhythm over the course of enamel formation. One of these is named accentuated brown striae of Retzius, which are also known as Wilson bands or accentuated lines (ALs, Nava et al., 2019; Witzel et al., 2008). These ALs reflect disruptions of the metabolic equilibrium due to physiological stresses (but see also Goodman and Rose, 1990; Lemmers et al., 2021; Schwartz et al., 2006, for psychological stresses in primates). One well-documented example of an AL occurs at birth. Birth is recorded in the form of a peculiar accentuated line called the neonatal line (Dean et al., 2019; Sabel et al., 2008). The neonatal line demarcates the pre-, and post-natal environment and as such is a critical landmark in studies of enamel microstructure that reconstruct timelines related to life history.

The microstructure of a dental crown that becomes visible through a thin section (Fig. 3B), represents a calendar of all the individual's life moments from the beginning of crown formation to its completion.

4. Developmental trajectories revealed in dental microstructure

Individual rates of somatic growth can be represented, albeit not perfectly, by dental tissues (Šešelj, 2017). It follows that the reconstruction of individual ontogenetic trajectories in both *Homo* and extant and fossil primates (Austin et al., 2023, 2013; Cerrito et al., 2022; Craig et al., 2009; Dean, 2010, 2016, 2017; Dean and Cole, 2013; Dean et al., 2020; Dean and Smith, 2009; Kubat et al., 2023; Li et al., 2022; Mahoney et al., 2022; Mahoney et al., 2021; Müller et al., 2019; Nava et al., 2017b; Nava et al., 2019; Nava et al., 2020; Olejniczak et al., 2008; Rosas et al., 2017; Smith et al., 2022; Smith et al., 2018b; Smith and Tafforeau, 2008) is made possible by the comparative study of the histology of mineralised dental tissues.

Human life history (our pattern of growth, maintenance, and reproduction) is unique. Compared to our closest living relatives, some aspects of it are accelerated (i.e. short spacing between births and early weaning) while others are decelerated (i.e. slow growth and delayed development). To understand its evolutionary history we can leverage the observation that our slow developmental trajectory is faithfully recorded in mineralized tissues (i.e. enamel, dentine and bone) and is reflected in a prolonged period of development and delayed dental and skeletal maturity (Dean and Smith, 2009; Guatelli-Steinberg, 2016; Leigh, 2001; Rosas et al., 2017; Šešelj, 2017; Smith, 1992). This slow growth in humans is probably an adaptation which permitted the growth and development of larger brains, which are energetically extremely expensive and therefore require an ontogenetic trade-off between neural development and skeletal development (Kuzawa et al., 2014). While across mammals there is a general trade-off between fertility and brain size (as both test the limit of maternal and allomaternal energetic input), humans stand out comparing to other mammals in that there is no brain size/fertility trade-off, and this is most likely a consequence of both paternal and alloparental care (Heldstab et al., 2019) and of increased fat storages (Heldstab et al., 2016; Navarrete et al., 2011).

Evidence about this trend of delayed development is derived from studies of infancy and childhood in the bioarchaeological and fossil record (Aiello and Dean, 1990; Aris et al., 2020; Bromage and Dean, 1985; Dean, 2000, 2006, 2009, 2010; Dean et al., 2001; Dean and Liversidge, 2015; Dean and Smith, 2009; Macchiarelli et al., 2006; Mahoney, 2015; Mahoney et al., 2021; Nava et al., 2017a; Nava et al., 2020; Smith, 1991; Smith, 2004; Smith, 2013), particularly with the study of the first permanent molar, which develops from birth till the end of the brain growth (Hillson, 2023). The chemical composition, the formation timing and the eruption age of permanent molars are effective proxies for some of life history benchmarks, like age at weaning, age at sexual maturity, age at first reproduction, inter-birth interval, natural life span (Humphrey et al., 2008a; Smith, 1991, 1992). To date, most dental paleoanthropologists recognize that some limitations exist about these correlations, especially when comparing living species with the fossil record, and some authors have questioned the validity of dental development and some aspects of eruption as a reliable proxy from which to infer life history variables (Robson and Wood, 2008). The relationship among the benchmarks, indeed, may have changed over time and the complex interplay between extrinsic (ecological niches) and intrinsic (physiology, somatic development) factors should be taken into account when inferring life history traits from the emergence of the first permanent molar (Guatelli-Steinberg, 2016; Smith, 2013).

The trend of delayed growth and development in humans is well known from the skeletal and dental analyses of a number of fossil and archaeological specimens, throughout the entire period of human natural history (e.g. Dean and Smith, 2009; Le Cabec et al., 2017; Rosas et al., 2017; Smith, 1992; Smith et al., 2004), as well as from the study of the extant great apes (Charnov and Berrigan, 1993; Walker et al., 2006). Conversely, very little has been explored on the critical period represented by intra-uterine life with few exceptions (Kierdorf et al., 2021; Mahoney, 2015; Mahoney et al., 2021; Nava et al., 2017a; Nava et al., 2017b; Witzel, 2014). Life in utero is a sheltered period when the selective forces driven by the environment are mediated and buffered to some extent by the maternal body and immune system, even if they are still acting on the mother-fetus relationship (Almond and Currie, 2011; Barker et al., 2002). Therefore, any attempt to reconstruct the prenatal and early postnatal growth trajectories can be of seminal importance for the understanding of the general pattern of slow growth and development of present-day humans. Moreover, recent evidence points out that the rate of adaptive evolution from the Neolithic is more than one hundred times higher than the rate that characterizes most of human evolution (Hawks et al., 2007). Not surprisingly, new genetic evidence shows that human adaptation continued well into historical times, with polygenic adaptation being an important force shaping both genotypic and phenotypic variation (Field et al., 2016). Consequently, the

expectation is to observe population-specific differences in fetal development and rapid and consistent changes through time. In addition, this model of fetal development appears to be supported by the Genome-Wide Association Study (GWAS), which points to a rapid selection in human recent past (Boyle et al., 2017; Field et al., 2016; Krapohl et al., 2017).

As teeth are the most frequent and best-preserved findings in the fossil and archaeological record, is it not surprising that some dental growth parameters are critical for assessing differential growth in past hominins. The daily enamel secretion rate (DSR, Fig. 3E) is the linear measure of enamel matrix secreted in one day by ameloblasts - the enamel-forming cells (Birch and Dean, 2014; FitzGerald and Hillson, 2009; Huda and Bowman, 1994; Macchiarelli et al., 2006; Mahoney, 2011, 2012, 2015; McFarlane et al., 2021; Nava et al., 2017a; Towle and Loch, 2024). This velocity is the basic parameter in evaluating dental growth trajectories and is calculated by dividing the lengths of prism segments by the corresponding number of daily increments (cross striations, CS) along them and is equivalent to the average length of a CS (Hillson, 2014). DSR varies along the crown profile and increases from the EDJ toward the outer enamel surface while decreasing from the tooth tip toward the neck (Beynon et al., 1991; Birch and Dean, 2009; Hillson, 2014; Mahoney, 2012; Massler and Schour, 1946; Nava et al., 2017a; Schour and Massler, 1937; Schour and Poncher, 1937). Fig. 4 shows the topographic distribution of DSR in a deciduous tooth, calculated by collecting randomly distributed DSR measurements (N>100) across the entire crown portion (Nava et al., 2017a; Peripoli et al., 2023).

Enamel extension rate (EER) is the rate of differentiation of secretory ameloblasts, or the rate at which secretory front ameloblasts are recruited along the enamel-dentine junction (EDJ, Fig. 3C) between the dentine horn and the neck (Dean, 2009; Guatelli-Steinberg et al., 2012; Shellis, 1984). Extension rates vary along the EDJ, decreasing from the tip of the dentine horn toward the neck (Dean, 2009, 2010; Nava et al., 2017a). Crowns of deciduous teeth have higher initial EERs than permanent teeth (Mahoney, 2015; Shellis, 1984). Enamel extension rates are negatively correlated with overall crown formation time.

Retzius periodicity (RP) is the number of cross striations between two adjacent Retzius lines (Dean, 1987; FitzGerald, 1998). This interval is believed to reflect a basic biorhythm (Bromage et al., 2009; Dean, 1987; Mahoney et al., 2016). In modern humans, RP of permanent teeth can vary between 5 and 12 days when compared between individuals (FitzGerald, 1995, 1998). Typically, RP remains constant within an individual, but RP can sometimes change between the anterior and posterior dentition of some individuals (McFarlane et al., 2020), and within a tooth that preserves evidence of an extreme stress event (Mahoney et al., 2017). Population mean values are generally centred around 7, 8, or 9 days (see McFarlane et al., 2020 for a review of the topic).

5. Inferring stress exposure from dental microstructures

The mortality profile and physiological stress exposureof children in any human population is a measure of the biocultural adaptability of the community (Goodman and Armelagos, 1989; Lewis, 2018). As evidenced by several epidemiological studies on modern populations (for a

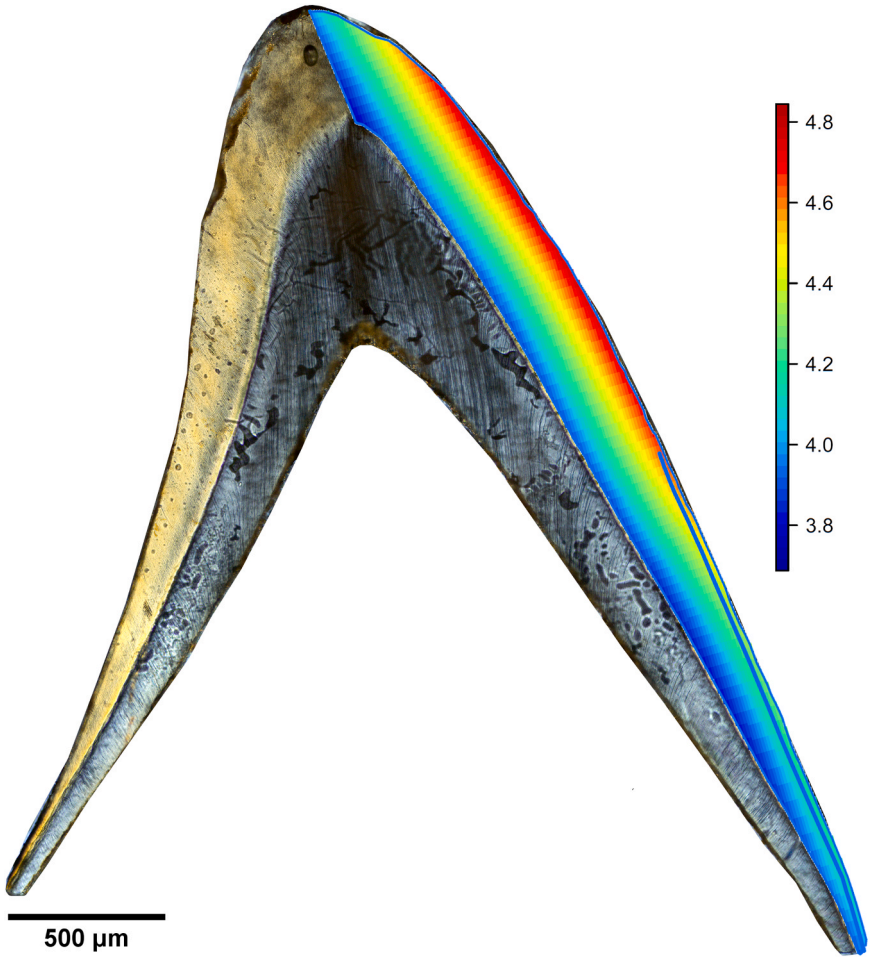

Fig. 4. The distribution of the daily secretion rates (DSR) represented as a pseudo-colour density map is superimposed on the photomosaic of the dental crown of a human deciduous incisor of an infant that died soon after birth. The neonatal line is highlighted by a thick blue line.

review see Humphrey and King, 2000), conditions during the early years of life - from intrauterine life to infancy - often affect poor health and early mortality in adulthood (Armelagos et al., 2009; Barker, 2004).

The study of the dental and skeletal remains of human archaeological populations allows us to infer their lifestyle in the past and to determine the degree of adaptation to the environment in which they lived. Lifespan may be considered the simplest and most direct indicator of such adaptation, but the frequency and chronology of non-fatal stressful events, such as disease or nutritional deficiencies, can provide important indications of the biological success of a population and are also unique tools in the context of palaeoepidemiological analyses (Armelagos et al., 1981; Goodman et al., 1988). The prevalence in a population of both microscopic (ALs) and macroscopic (linear enamel hypoplasia) enamel defects is often interpreted as a measure of general health during childhood (Larsen, 2015; Lorentz et al., 2019; Nava et al., 2019; Peripoli et al., 2023; Simpson, 1999; Żądzińska et al., 2015). Indeed, dental enamel is a highly specialised tissue that is very sensitive to physiological and environmental changes (Klein et al., 2017). Consequently, amelogenesis can be disrupted by systemic external stressors, producing permanent enamel defects (FitzGerald and Rose, 2000; FitzGerald and Saunders, 2005; Witzel et al., 2008). Stresses causing metabolic disturbances have been associated with a range of infant morbidity events, including malnutrition, low birth weight, maternal infections during pregnancy, infections and malnutrition during weaning, and many common childhood febrile illnesses (Birch and Dean, 2014; Hillson, 2023; Schultz et al., 1998; Seow, 1992; Skinner and Goodman, 1992; Teivens et al., 1996; Witzel et al., 2008). In addition, by calculating crown formation times, the relative chronology of ALs can be determined by directly counting daily cross-striations or Retzius lines (for a methodological review see FitzGerald and Saunders, 2005; Guatelli-Steinberg et al., 2012; Lemmers et al., 2021; Nava et al., 2017b; Nava et al., 2019). In teeth that possess the neonatal line, it is also possible to reconstruct the absolute chronology of stresses in an individual's life, and, considering several teeth from the same individual (since portions of dental crowns that are formed at the same time usually have the same AL patterns), it is possible to identify chronological intervals of homologous ALs on two or more teeth (Lemmers et al., 2021; Nava et al., 2017b, 2019).

In Nava et al. (2019), the chronology of ALs in an Imperial Roman sample has been derived by matching homologous intervals between ALs on several teeth of the same individual. The approach can be likened to a longitudinal approach, in that each individual is 'followed' throughout the formation of the selected teeth. A sample of 18 individuals with a total of 84 teeth (17 deciduous and 67 permanent) from the Roman Imperial necropolis of Isola Sacra (2nd to 4th century CE, Italy) were selected in Nava et al. (2019) study. Fig. 5 shows the contribution (density lines) of the individual tooth classes superimposed on the general trend (histogram) of the crude count of ALs in the sample during the first 69 months of life (corresponding to 5 years/9 months). The whole sample distribution is asymmetrical with a mode around the 11th month of life. In the first month, the frequency of stresses is rather low, then, the frequencies grow rapidly until the 11th - 13th month, with a slight peak at the 4th month. After the modal months, the distribution decreases until the 22nd month. Between the 22nd and the 44th month, the distribution is mostly stable with some wavering toward the end of the distribution. The last 24 months are characterized by a very low frequency of stress events. A possible interpretation of this general trend is that the first months of life are usually protected by the presence of maternally derived antibodies (Glezen, 2003) that directly relate to the low ALs prevalence figures observed during this period of life. When comparing the ALs profile with previously published stable nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) isotopes bulk bone collagen data derived from the children's ribs of the same necropolis (Prowse et al., 2008), the authors hypothesize weaning as the main factor shaping the stress distribution around one year of life in the sample.

It is possible to see how the contribution of the different tooth classes weigh differently during the period of their formation. In fact, the different tooth types considered do not seem to record physiological stress in the same way, and the location of the stressor on the crown is important as well. The central part of the crown consistently is more likely to preserve evidence of stressor, compared to the cuspal and cervical regions. It, therefore follows that an effective reconstruction of the health status of a population in the past using accentuated lines, but also enamel hypoplasias, cannot be based on the evidence of a single tooth, which will always tend to underestimate the number of stress events in the initial period of its formation and the final period.

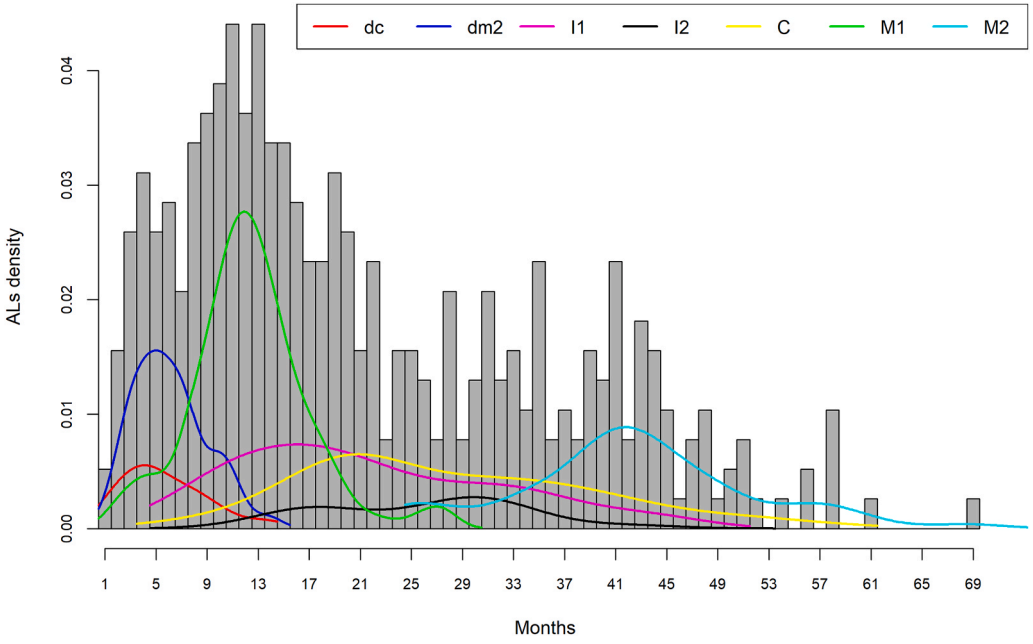

Fig. 5. Disaggregation of the raw ALs' count by tooth classes, approximated by the density estimates. The density curves are superimposed to the crude count distribution during the first 69 months of life (from Nava et al. 2019 Fig. 4).

6. Diet and mobility inferred from the biogeochemical analysis of dental mineralised tissues

In recent decades, the use of 'bulk isotope analyses', i.e. those utilizing several mg-sized samples thus averaging the signal over a broad time range, has played a crucial role in elucidating aspects such as diet, mobility and the broader interaction between humans and their environment. Such geochemical analyses commonly target either the collagenous (i.e. organic) portion of skeletal remains or the mineral phases (i.e. hydroxylapatite). Specifically, carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$) and sulfur ($^{34}S/^{32}S$) stable isotopes (commonly expressed in ‰ in δ-notation (e.g. $\delta^{13}C$…) vs. international standards) are measured on the collagen of human and animal bones/teeth and can reveal the trophic position (Schwarcz and Schoeninger, 2012) and, in case of S, the mobility of the individual (Richards et al., 2001). Oxygen ($^{18}O/^{16}O$), carbon, strontium ($^{87}Sr/^{86}Sr$) and lead isotopes ($^{20x}Pb/^{204}Pb$; x=8, 7 or 6) are measured on the mineral phase(s) of tooth enamel – both the phosphate and the carbonate moiety depending on the analyte and the technique – and provide information on mobility (O, Sr, Pb) (Alt et al., 2014; Eckardt et al., 2009; Evans et al., 2022; Lugli et al., 2022b; Müller et al., 2003), diet (C) (Ambrose and Norr, 1993) and the environment (O, C) (Pederzani and Britton, 2019) where the individual lived. Recently, N isotopes have been also measured on the organic matter (~1 %) encapsulated in tooth enamel (Leichliter et al., 2021), as a novel method to obtain biogenic N isotope ratios in case of poor collagen preservation, e.g. in 'deep time'.

Yet, two main issues arise from the use of 'bulk' isotopes for life-history reconstruction, namely 1) the lack of intra-life temporal resolution and 2) the poor preservation of collagen in fossil remains. While the latter issue can be (partially) solved by focusing on dental enamel only, also exploiting novel non-traditional stable isotope systematics (e.g. Zn, Jaouen et al., 2022, Ca, Dodat et al., 2021; Li et al., 2022; Li et al., 2016; Tacail et al., 2017), the former issue is more challenging to address. In this sense, much work has been devoted to measuring the isotope composition of incremental tissues – such as e.g. dentine and enamel – by exploiting intra-tooth sampling strategies, for example, analysing enamel (Zazzo et al., 2012) or dentine (Cheung et al., 2022) serial samples drilled/sawed from tooth specimens. However, even though these methods are suitable for various contexts, they still suffer from insufficient temporal resolution (Tsutaya, 2020), being able to solve diet and mobility changes at about multi-montly/sub-annual scale, due to either instrumental limits (sample size and collection) or chronologization problems. There have been attempts to improve bulk sampling techniques that should reduce the impact of this issue (Beaumont et al., 2014; Curtis et al., 2022). When combined with dental histomorphometry, micro-sampling techniques – above all laser ablation (LA) – applied to incremental tissues can help improve the achievable spatial resolution and possibly resolve individual life histories at a sub-monthly scale (Kubat et al., 2023; Müller et al., 2019, 2009; Nava et al., 2020). In particular, LA can be coupled with ICPMS and MC-ICPMS to measure elemental ratios (Müller et al., 2019)– as e.g. Sr/Ca, Ba/Ca and Pb/Ca – and isotope ratios (Lugli et al., 2022b; Müller and Anczkiewicz, 2016) – as e.g. $^{87}Sr/^{86}Sr$ – with a lateral resolution of few μm (< 10 μm) and a spot size ranging between 10 and 100 μm.

In recent years, high spatial resolution elemental analyses of Sr/Ca and Ba/Ca ratios (Arora and Austin, 2013; Austin et al., 2013; Humphrey et al., 2008a, 2008b; Joannes-Boyau et al., 2019; Müller and Eggins, 2003; Müller et al., 2019; Nava et al., 2020; Smith et al., 2023) have been successfully used to reconstruct feeding behaviour in early life and weaning practices of past and recent hominins (Kubat et al., 2023; Lugli et al., 2022b; Müller et al., 2019; Nava et al., 2020; Smith et al., 2023, 2022). Sr and Ba share similarities with calcium (Ca) being alkaline earth elements with a divalent charge, but they have larger ionic radii (Sr: 1.18, Ba: 1.35, Ca: 1.00 Å) (Shannon, 1976) and no known major biological function in the body (Burton et al., 1999). Although they follow calcium metabolism, their larger size results in discrimination (i.e. Ca is preferentially selected) in the gastrointestinal tract (Elias et al., 1982). From there, ions are mainly fixed *via* plasma in the skeletal tissue, with further discrimination relative to Ca (Balter, 2004). This leads to ~5-fold lower Sr/Ca and Ba/Ca ratios in bones and teeth compared to the diet, a phenomenon known as *biopurification* (Burton et al., 1999). Interestingly, during human growth, discrimination against Sr and Ba relative to Ca ions progressively increases, becoming significant at around one year of age (Price et al., 1986). This suggests that the Sr/Ca and Ba/Ca ratios in infant plasma should closely align with the values of the dietary inputs. Published data indicates that mammary glands exhibit greater discrimination for strontium (2.5-fold) compared to the placenta (1.7-fold), resulting in average strontium-to-calcium values in breastmilk being lower than those in the umbilical cord (fetal) values (Nava et al., 2020; Rossipal et al., 2000). Importantly, the chemical composition of fetal blood is preserved in prenatal dental enamel, while postnatal enamel reflects breastmilk consumption. Consequently, elevated Sr/Ca signals in prenatal areas, followed by reduced postnatal Sr/Ca levels, serve as indicators of breastmilk consumption (Humphrey, 2014; Humphrey et al., 2008a; Nava et al., 2020).

Unlike Sr, interpreting Ba/Ca data is challenging due to conflicting data in the literature and a lack of studies on barium metabolism (Krachler et al., 1999a; Peek and Clementz, 2012). Research on dental enamel indicates that barium generally behaves similarly to strontium, decreasing with breast milk consumption and increasing with the introduction of transitional foods (Peek and Clementz, 2012). However, barium's behaviour in tooth enamel appears to be less predictable than that of strontium, possibly due to the high variability of barium content in human milk, colostrum, and formulas (Krachler et al., 1999b; Müller et al., 2019).

In addition to dietary shifts, conducting multi-elemental analyses on teeth using LA-ICPMS (Fig. 2) can provide insights into health issues and exposures to toxic trace metal(loid)s, such as cadmium (Cd), mercury (Hg) and lead (Pb), during in-utero development, infancy, and childhood (Gerbi et al., 2022; Maret, 2022; Needleman et al., 1979; Schildroth et al., 2023). This helps identify exposure events during critical life stages, such as, for example, brain development. Moreover, peaks of specific trace elements are expected within dentine and enamel during stress and or pathological events, due to the rebuffering of elemental stores from the skeleton or deficiency (Austin et al., 2016; Müller et al., 2009; Obtel et al., 2022).

The study of the spatial distribution of trace elements by LA-ICPMS can be achieved with two main different approaches: 1) histologically-driven profile analysis, according to specific tooth growth trajectories previously determined by histomorphometry (e.g. Fig. 6) (Linscott et al., 2023; Müller et al., 2019) or 2) distribution maps across the tooth cross-section (Arora and Austin, 2013; Austin et al., 2013; Dean et al., 2019; Hare et al., 2011; Joannes-Boyau et al., 2019; Smith et al., 2018a).

Both methodologies retain their merits and limits. For example, while the former method does not yield a broad overview of the element distribution across the tooth, it does provide better lateral resolution coupled with much faster analytical time. In this sense, the method defined by Müller et al. (2019) proposes to analyze at least two LA traces along the EDJ of both buccal and lingual aspects, in which the enamel maturation overprint is minimal and the contribution of the secretion signal is maximal. In addition, at least two LA tracks are analyzed along two different enamel prisms. These serve as a control for an evaluation of the EDJ signal – although prisms are partially overprinted by maturation and thus monitor the topographic changes in enamel, e.g. the expected increase of Zn that is upregulated toward the outer enamel (Müller et al., 2019). On the other hand, the 2D-mapping approach offers a better overall view of the elemental distribution of the sample, but it is time-consuming and less spatially resolved; also, elemental images are difficult to convert to days of life due to the non-linear time of secretion across the enamel (Austin et al., 2016). Ultimately time-resolved profiles remain the gold standard for life history

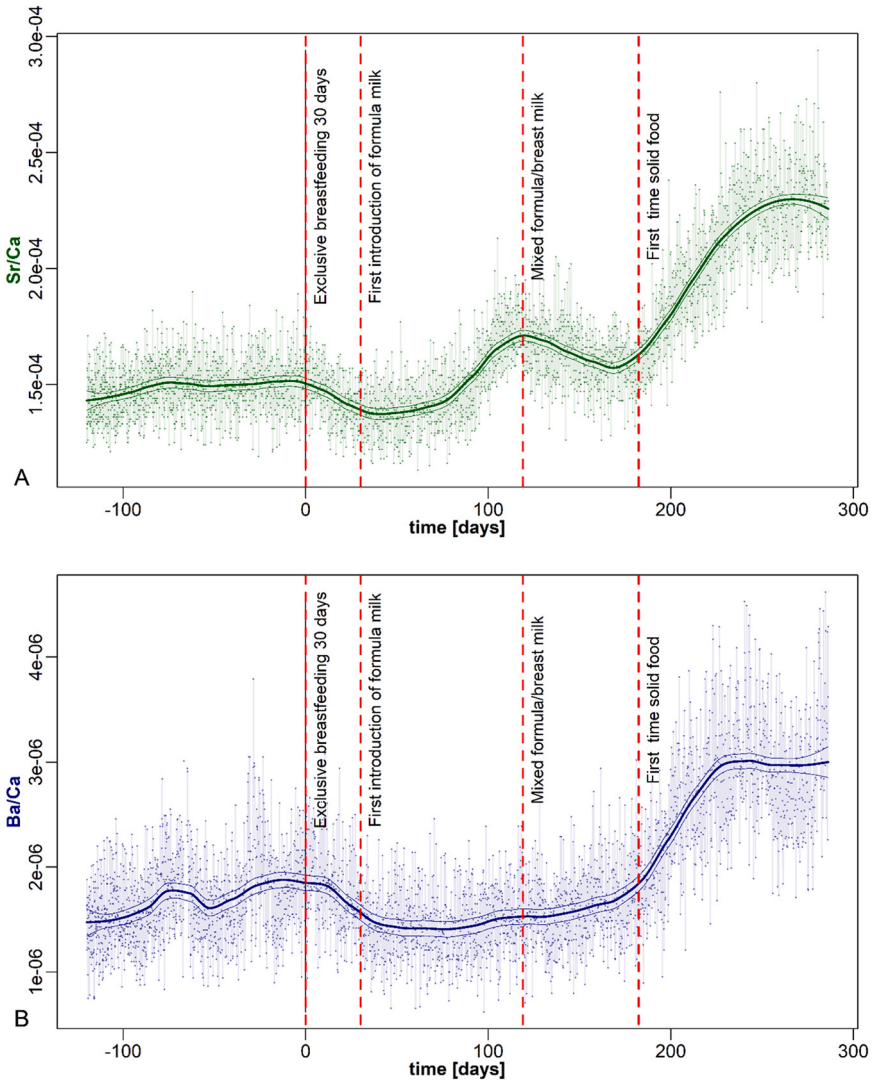

Fig. 6. Sr/Ca (A) and Ba/Ca (B) profiles along the EDJ in a contemporary individual with a known dietary history. The vertical black lines indicate the major events in the first 9 months after birth. Data from Nava et al. (2020).

reconstructions whether directly analysed or reconstructed from 2D maps.

When coupled with a multi-collector ICPMS, laser ablation sampling allows the reconstruction of high-temporally resolved (sub-monthly) mobility histories of individuals. This is accomplished by measuring the $^{87}Sr/^{86}Sr$ isotope ratio – a common proxy for provenance due to its link with the local geology (see e.g. Bentley, 2006 for a review) – along the EDJ, thus obtaining isotope profiles that represent (possible) mobility events during specific stages of life (Lugli et al., 2022b; Müller and Anczkiewicz, 2016). These data can be compared with local proxies and regional/national scale *isoscapes* (i.e. isotope maps, Bataille et al., 2020; Lugli et al., 2022a), to possibly resolve the movements of the individual across the landscape (Lugli et al., 2022b) (see as an example Fig. 7). Moreover, examining deciduous teeth or permanent first molars that develop during pregnancy and early childhood provides insights into maternal movements. This information, especially among hunter-gatherer groups, can be extrapolated to encompass the entire human group or family, which is important to study the life histories of prehistoric communities (Lugli et al., 2017, 2022b; Nava et al., 2020).

7. Conclusions: dental microstructure, life history, evolution of human cooperation and cognition, and clinical relevance - looking forward

Dental enamel, which is the focus of the present review, tells us about early nursing history and childhood life history events which are unquestionably vital demographic components that help reveal how population structure comes to be. Additionally, the other dental tissues, i.e. dentine and cementum, can record other human life history benchmarks like age at first reproduction, parturition and interbirth intervals. Human permanent enamel formation continues into the adolescent years, root dentine is complete at about 23 years of age (AlQahtani et al., 2010), while cementum grows continuously from tooth eruption until death. Accentuated lines in the third molar tooth (wisdom tooth) root can record evidence of parturition during adolescence (Dean and Elamin, 2014), although there are challenges in accurately accessing this information (Liversidge, 2008; Zandi et al., 2015).

Cementum coats the external surface of the root, starting its deposition after a tooth has erupted, (Perrone et al., 2022). Unlike enamel and dentine, which form with a circadian rhythm, cementum increments form over an annual cycle and because this continues throughout an individual's life it can be drawn upon to estimate adult age-at-death.

Additionally, cementum can inform on important adult life history

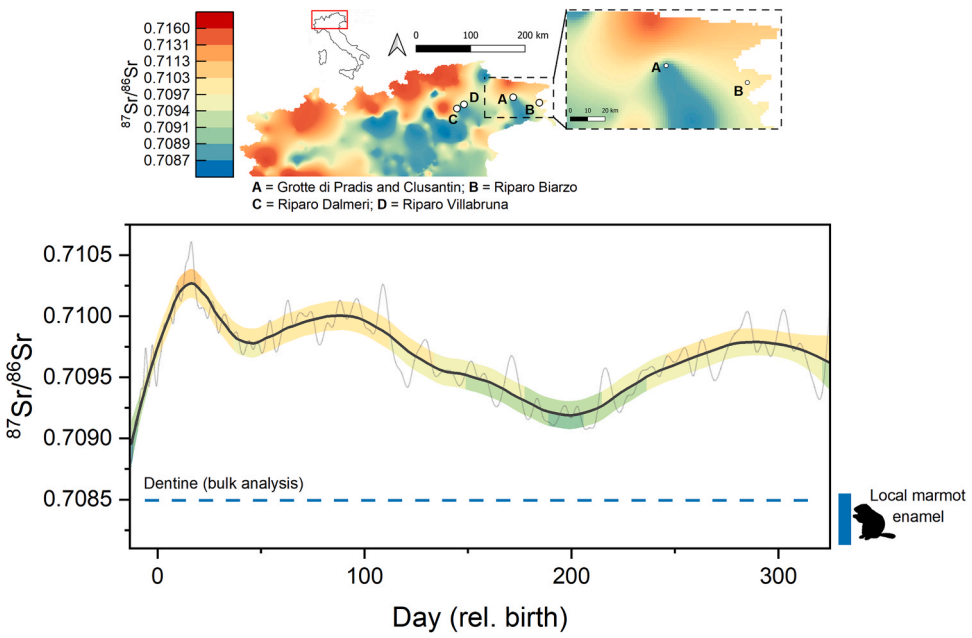

Fig. 7. Time-resolved Sr isotope profile measured along the EDJ of Pradis 1 tooth enamel (top panel); the signal is smoothed through a locally weighted polynomial regression fit (LOWESS), with its associated standard error (± 2 SE); the 2 SE bands are color-coded according to the isoscape ranges of the bottom panel. Reference local values (marmots' enamel and Pradis 1 dentine) are also reported in the graph as a comparison. The Sr isoscape model reported in the bottom panel is from Lugli et al. (2022a) and represents the isotope variability of the bioavailable Sr pool in Northern Italy. Overall, the human group from Grotte di Pradis was seasonally mobile, with Sr isotope values not compatible with the site. This figure is modified from Lugli et al. (2022b).

events such as parturition (Newham and Naji, 2022) and menopause (Cerrito et al., 2020; Newham and Naji, 2022) and therefore holds great potential for studying the evolution of these events.

Reconstructing the evolution of human life history through the analysis of dental microstructure has implications for our understanding of the evolution of human cooperation cognition and communication (Hrdy and Burkart, 2020; Van Schaik and Burkart, 2010). As reviewed above, teeth contain a faithful record of an infant's age at weaning, which in humans is much earlier (both chronologically and in terms of neural development) than expected for a primate of our body size (Hawkes and Finlay, 2018; Robson et al., 2006). Such early age at weaning is correlated, both in humans (Kramer, 2010) and across mammals (Cerrito and Spear, 2022), with the presence of alloparental care: if help is available, mothers can wean their infants earlier and resume cycling, thus increasing their reproductive frequency. In turn, the reliance on alloparental care during a critical period in brain development exposes the maturing brain to a variety of social interactions on which the infant's life depends upon – making the infant also susceptible to develop impairments in adult socio-cognitive abilities shall it experience social adversities during childhood (e.g. Dunn et al., 2013; Germine et al., 2015). The developing infant must learn to elicit care from non-maternal caregivers who are not hormonally primed to do

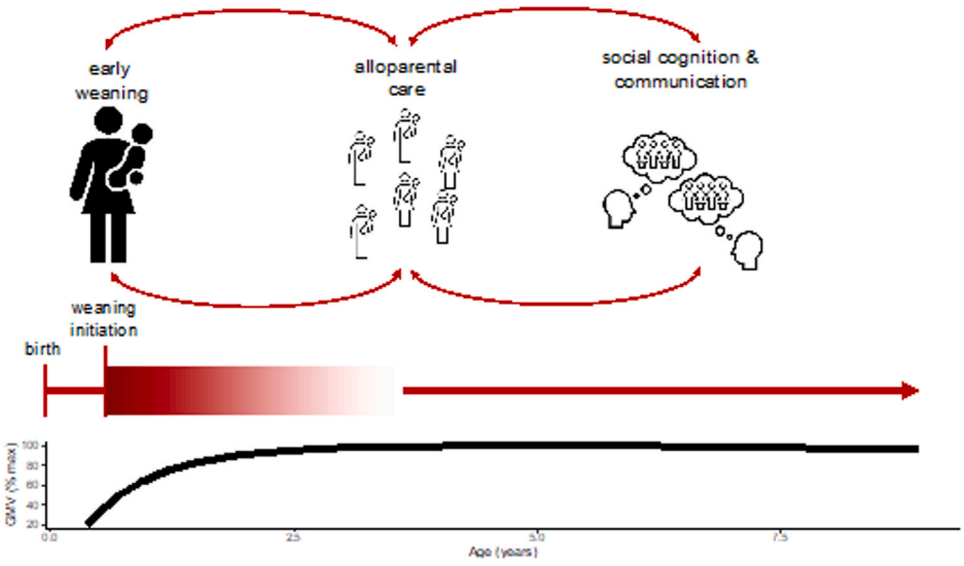

Fig. 8. Developmental trajectory of gray matter volume (GMV) in humans (data from Bethlehem et al. 2022) in relation to age at weaning and consequent infant-caregiver interactions. Age at weaning initiation is reported as 6 months (based on World Health Organization, 2023) while the transitional period is extremely variable between cultures (Sellen, 2009) and is represented here by a shaded area terminating between 2 and 3 years of age. After weaning initiation, and exactly during a critical period of brain development, human infants begin engaging in care-eliciting behaviors with a multitude of adults, thus "tuning" their social brain.

so. Comparative research has shown that the elicitation of care from non-maternal caregivers has co-evolved with brain structures involved in both non-verbal communication (Cerrito and DeCasien, 2021) and emotion regulation (Cerrito and Burkart, 2023). It this therefore during the earliest stage of postnatal development (0–2 years) that the brain circuitries involved in social cognition are "tuned" (Grossmann and Johnson, 2007). It is the interaction between "nature" (neuro-developmental trajectory) and "nurture" (presence of alloparents as functionally correlated with early weaning) that sets the stage for the development of the social brain (Kenkel et al., 2017) (Fig. 8). However, despite the importance of understanding our unusually-early age at weaning, little is known regarding its evolution during the process of homination (last 6–8 million years). Indeed, while it seems that Neanderthal age at weaning was similar to that of modern humans (Nava et al., 2020) almost nothing is known regarding other hominin species (but see Joannes-Boyau et al., 2019). Future work on fossil deciduous teeth will therefore be instrumental for the reconstruction not only of our early life-history events but also of our cooperative and cognitive traits that likely co-evolved with our nursing practices.

Besides reconstructing past individuals' life histories, teeth also can function as a retrospective archive of somatic growth trajectories, stress, and environmental exposures for contemporary individuals, with clinical relevance. Perinatal exposure to toxins and other environmental chemicals is linked to health issues in children, including impaired neurodevelopment and metabolic syndrome (Salazar et al., 2021; Sanders et al., 2018; Wang et al., 2014). Prenatal exposure to increased testosterone concentrations such as in mothers affected by polycystic ovary syndrome (Cherskov et al., 2018), has been linked to the development of autism spectrum disorder (Baron-Cohen et al., 2006). Given the potential of teeth in maintaining a record of systemic levels of steroid hormones (Quade et al., 2021), future research can shed light on both the evolution of the maternal endocrine system during gestation, and on the potential implications that this had on neurodiversity in past populations. Aside from chemical exposure, other early life circumstances, including stress and adversity, have a proven effect on an individual's brain development (Scheinost et al., 2016), with possible adverse effects on mental health later in life (Ben-Shlomo and Kuh, 2002; Dunn et al., 2018). As such, monitoring, prevention and intervention during sensitive periods of development are crucial to paediatricians and epidemiologists. While clinicians routinely have access to biomarkers like blood, saliva, and urine for health monitoring of both mothers and perinates, such markers often lack the precision required to study crucial vulnerability windows. Additionally, such samples merely offer a snapshot in time rather than recording an incremental record, the former potentially not being fully representative given the well-documented seasonal variability of blood Pb levels (e.g. Filippelli et al., 2005). Teeth however can register both prenatal and postnatal exposure histories of individuals, and in the last decade, there has been a growing recognition among clinical researchers of the temporal registration and archival potential of teeth in such contexts (Andra et al., 2015; Arora and Austin, 2013; Davis et al., 2020; Dunn et al., 2022). Additionally, the non-invasive nature of deciduous tooth sample collection, as they are naturally exfoliated starting around the age of 6, makes them a powerful potential biomarker for retrospective assessment of maternal and fetal health during pregnancy and early life.

Recent work by Davis et al. (2020) pointed out how specifically insights learned from biological anthropology could be applied to establish new lines of clinical research on the use of teeth as biomarkers to guide disease prevention (Davis et al., 2020), serving as a first-line asset for early screening and interventions to prevent future illness (Davis et al., 2020; Dunn et al., 2022). For example, Mahoney et al. (2022) observed a link between the RP of deciduous molars, maturation rates and obesity in a prospective cohort study of young adolescents. As such, biological anthropological studies contribute both to the study of the human past as well as modern human environmental adaptation and interaction. In return, if clinical studies of dental microstructure can be implemented on a large scale, combining histological and chemical temporal registered data with fine-grained life history data from well-documented cohort studies (e.g. Dunn et al., 2019; Fraser et al., 2013; Stein et al., 2015) there is great potential to put archaeological and bioanthropological studies of teeth in a broader context: Modern cohort studies can contain a wealth of highly detailed life history and demographic details of individuals to whom the deciduous teeth belonged before being naturally exfoliated. Such detailed information can give us a much better understanding of the underlying drivers of individual variation in dental development and pathways in which chemical and stress signatures get integrated into an individual's dental microstructure. The level of detail available via cohort studies could never be obtained from the archaeological record alone, and as such, teeth are a truly versatile medium to study life history with implications for human evolution in deep and recent times.

Declaration of Competing Interest

None

Acknowledgements

AN received funding from the European Research Council (ERC) under the European Union's Horizon Europe Research and Innovation Programme (GA no. 101077348 — MOTHERS; https://erc-mothers.eu/). FL and SL are supported by the European Union's Horizon Europe Research and Innovation programme under the Marie Skłodowska-Curie PF action (FL GA no. 101104566 — AROUSE and SL GA no. 101065448 — ENIGMA). PM acknowledges support from The Royal Society and The Leverhulme Trust (grant numbers RG110435 and RPG-2018-226). WM acknowledges support through the VeWA consortium (Past Warm Periods as Natural Analogues of our high-CO2 Climate Future) by the LOEWE programme of the Hessen Ministry of Higher Education, Research and the Arts, Germany, and Deutsche Forschungsgemeinschaft grant MU 3739/2–1. FIERCE is financially supported by the Wilhelm and Else Heraeus Foundation and by the Deutsche Forschungsgemeinschaft (DFG: INST 161/921-1 FUGG, INST 161/923-1 FUGG and INST 161/1073-1 FUGG), which is gratefully acknowledged.

References

Agarwal, S.C., 2016. Bone morphologies and histories: Life course approaches in bioarchaeology. Am. J. Phys. Anthropol. 159, 130–149.
Aiello, L., Dean, M.C., 1990. An Introduction to Human Evolutionary Anatomy. Academic Press, London.
Almond, D., Currie, J., 2011. Killing me softly: the fetal origins hypothesis. J. Econ. Perspect. 25 (3), 153–172.
AlQahtani, S.J., Hector, M., Liversidge, H., 2010. Brief communication: the London atlas of human tooth development and eruption. Am. J. Phys. Anthropol. 142 (3), 481–490.
Alt, K.W., Knipper, C., Peters, D., Müller, W., Maurer, A.-F., Kollig, I., Nicklisch, N., Müller, C., Karimnia, S., Brandt, G., 2014. Lombards on the move–an integrative study of the migration period cemetery at Szólád, Hungary. PloS One 9 (11), e110793.
Ambrose, S.H., Norr, L., 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. Prehistoric human bone: archaeology at the molecular level. Springer, pp. 1–37.
Andra, S.S., Austin, C., Arora, M., 2015. Tooth matrix analysis for biomonitoring of organic chemical exposure: current status, challenges, and opportunities. Environ. Res. 142, 387–406.
Antoine, D., Hillson, S., Dean, M.C., 2009. The developmental clock of dental enamel: a test for the periodicity of prism cross-striations in modern humans and an evaluation of the most likely sources of error in histological studies of this kind. J. Anat. 214, 45–55.
Aris, C., Mahoney, P., O'Hara, M.C., Deter, C., 2020. Enamel thickness and growth rates in modern human permanent first molars over a 2000 year period in Britain. Am. J. Phys. Anthropol. 173 (1), 141–157.
Armelagos, G.J., Goodman, A.H., Harper, K.N., Blakey, M.L., 2009. Enamel hypoplasia and early mortality: bioarcheological support for the Barker hypothesis. Evolut. Anthropol.: Issues, N., Rev. 18 (6), 261–271.

Armelagos, G.J., Jacobs, K.H., Martin, D.L., 1981. Death and demography in prehistoric Sudanese Nubia. In: Humphreys, S.C., King, H. (Eds.), Mortality and Immortality: The Anthropology and Archaeology of Death. Academic Press, London, pp. 33–57.
Arora, M., Austin, C., 2013. Teeth as a biomarker of past chemical exposure. Curr. Opin. Pediatr. 25 (2), 261–267.
Austin, C., Kumar, P., Carter, E.A., Lee, J., Smith, T.M., Hinde, K., Arora, M., Lay, P.A., 2023. Stress exposure histories revealed by biochemical changes along accentuated lines in teeth. Chemosphere 329, 138673.
Austin, C., Smith, T.M., Bradman, A., Hinde, K., Joannes-Boyau, R., Bishop, D., Hare, D. J., Doble, P., Eskenazi, B., Arora, M., 2013. Barium distributions in teeth reveal early-life dietary transitions in primates. Nature 498 (7453), 216–219.
Austin, C., Smith, T.M., Farahani, R.M., Hinde, K., Carter, E.A., Lee, J., Lay, P.A., Kennedy, B.J., Sarrafpour, B., Wright, R.J., 2016. Uncovering system-specific stress signatures in primate teeth with multimodal imaging. Sci. Rep. 6, 18802.
Balter, V., 2004. Allometric constraints on Sr/Ca and Ba/Ca partitioning in terrestrial mammalian trophic chains. Oecologia 139 (1), 83–88.
Barker, D.J., 2001. Fetal and infant origins of adult disease. Mon. Kinderheilkd. 149 (1), S2–S6.
Barker, D.J., 2004. The developmental origins of adult disease. J. Am. Coll. Nutr. 23 (sup6), 588S–595S.
Barker, D.J., Eriksson, J.G., Forsén, T., Osmond, C., 2002. Fetal origins of adult disease: strength of effects and biological basis. Int. J. Epidemiol. 31 (6), 1235–1239.
Baron-Cohen, S., Lutchmaya, S., Knickmeyer, R., 2006. Prenatal testosterone in mind: Amniotic fluid studies. MIT Press.
Bataille, C.P., Crowley, B.E., Wooller, M.J., Bowen, G.J., 2020. Advances in global bioavailable strontium isoscapes. Palaeogeogr., Palaeoclimatol., Palaeoecol. 555, 109849.
Baxter, J.E., 2022. The archaeology of childhood. Rowman & Littlefield.
Beaumont, J., Gledhill, A., Montgomery, J., 2014. Isotope analysis of incremental human dentine: towards higher temporal resolution. Bull. Int. Assoc. Paleodont. 8 (2), 212–223.
Ben-Shlomo, Y., Kuh, D., 2002. A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives. Oxford University Press, pp. 285–293.
Bentley, R.A., 2006. Strontium isotopes from the earth to the archaeological skeleton: a review. J. Archaeol. Method Theory 13 (3), 135–187.
Bethlehem, R.A., Seidlitz, J., White, S.R., Vogel, J.W., Anderson, K.M., Adamson, C., Adler, S., Alexopoulos, G.S., Anagnostou, E., Areces-Gonzalez, A., 2022. Brain charts for the human lifespan. Nature 604 (7906), 525–533.
Beynon, A.D., Dean, M.C., Reid, D.J., 1991. On thick and thin enamel in hominoids. Am. J. Phys. Anthropol. 86 (2), 295–309.
Birch, W., Dean, M.C., 2009. Rates of enamel formation in human deciduous teeth. Comparative Dental Morphology. Karger Publishers, pp. 116–120.
Birch, W., Dean, M.C., 2014. A method of calculating human deciduous crown formation times and of estimating the chronological ages of stressful events occurring during deciduous enamel formation. J. Forensic Leg. Med. 22, 127–144.
Bondioli, L., Nava, A., Sperduti, A., 2020. In: Nizzo, V. (Ed.), I Hope the Ancients Loved Their Children Too. Gli Infanti nel Record Archeo-Antropologico tra Invisibilità, Pratiche di Infanticidio e Fenomeni di Reproductive Wastage.. Antropologia e Archeologia Dell'Amore, Rome, pp. 26–28.
Bondioli, L., Nava, A., Rossi, P.F., Sperduti, A., 2016. Diet and health in central-southern italy during the roman imperial time. ACTA IMEKO 5 (2), 19–25.
Boyde, A., 1963. Estimation of age at death of young human skeletal remains from incremental lines in the dental enamel. Third International Meeting in Forensic Immunology, Medicine, Pathology and Toxicology. Wiley-Liss, London, pp. 36–37.
Boyde, A., 1964. Boyde A. 1964. The structure and development of mammalian enamel [PHd Thesis]: Queen Mary, University of London..
Boyde, A., 1989. Enamel. Teeth Handbook of Microscopic Anatomy (Continuation of Handbuch der mikroskopischen Anatomie des Menschen). Berlin. Springer, pp. 309–473.
Boyle, E.A., Li, Y.I., Pritchard, J.K., 2017. An expanded view of complex traits: from polygenic to omnigenic. Cell 169 (7), 1177–1186.
Bromage, T.G., 1991. Enamel incremental periodicity in the pig-tailed macaque: a polychrome fluorescent labeling study of dental hard tissues. Am. J. Phys. Anthropol. 86 (2), 205–214.
Bromage, T.G., Dean, M.C., 1985. Re-evaluation of the age at death of immature fossil hominids. Nature 317 (6037), 525–527.
Bromage, T.G., Lacruz, R.S., Hogg, R., Goldman, H.M., McFarlin, S.C., Warshaw, J., Dirks, W., Perez-Ochoa, A., Smolyar, I., Enlow, D.H., 2009. Lamellar bone is an incremental tissue reconciling enamel rhythms, body size, and organismal life history. Calcif. Tissue Int. 84 (5), 388–404.
Brüne, M., Schiefenhövel, W., 2019. The Oxford handbook of evolutionary medicine. Oxford University Press.
Burkart, J.M., Van Schaik, C.P., 2010. Cognitive consequences of cooperative breeding in primates? Anim. Cogn. 13, 1–19.
Burton, J.H., Price, T.D., Middleton, W.D., 1999. Correlation of bone Ba/Ca and Sr/Ca due to biological purification of calcium. J. Archaeol. Sci. 26 (6), 609–616.
Cerrito, P., Bailey, S.E., Hu, B., Bromage, T.G., 2020. Parturitions, menopause and other physiological stressors are recorded in dental cementum microstructure. Sci. Rep. 10 (1), 5381.
Cerrito, P., Burkart, J.M., 2023. Human amygdala volumetric patterns convergently evolved in cooperatively breeding and domesticated species. Hum. Nat. 34 (3), 501–511.
Cerrito, P., DeCasien, A.R., 2021. The expression of care: alloparental care frequency predicts neural control of facial muscles in primates. Evolution 75 (7), 1727–1737.
Cerrito, P., Nava, A., Radovčić, D., Borić, D., Cerrito, L., Basdeo, T., Ruggiero, G., Frayer, D.W., Kao, A.P., Bondioli, L., et al., 2022. Dental cementum virtual histology of Neanderthal teeth from Krapina (Croatia, 130–120 kyr): an informed estimate of age, sex and adult stressors. J. R. Soc. Interface 19 (187), 20210820.
Cerrito, P., Spear, J.K., 2022. A milk-sharing economy allows placental mammals to overcome their metabolic limits. Proc. Natl. Acad. Sci. 119 (10), e2114674119.
Charnov, E.L., Berrigan, D., 1993. Why do female primates have such long lifespans and so few babies? Or life in the slow lane. Evolut. Anthropol.: Issues, N., Rev. 1 (6), 191–194.
Cherskov, A., Pohl, A., Allison, C., Zhang, H., Payne, R.A., Baron-Cohen, S., 2018. Polycystic ovary syndrome and autism: a test of the prenatal sex steroid theory. Transl. Psychiatry 8 (1), 136.
Cheung, C., Fernández-Crespo, T., Mion, L., Di Giusto, M., Goude, G., Macdonald, R.A., Richards, M.P., Herrscher, E., 2022. Micro-punches versus micro-slices for serial sampling of human dentine: striking a balance between improved temporal resolution and measuring additional isotope systems. Rapid Commun. Mass Spectrom. 36 (21), e9380.
Courchesne, E., Pierce, K., Schumann, C.M., Redcay, E., Buckwalter, J.A., Kennedy, D.P., Morgan, J., 2007. Mapping early brain development in autism. Neuron 56 (2), 399–413.
Craig, O.E., Biazzo, M., O'Connell, T.C., Garnsey, P., Martinez-Labarga, C., Lelli, R., Salvadei, L., Tartaglia, G., Nava, A., Renò, L., 2009. Stable isotopic evidence for diet at the Imperial Roman coastal site of Velia (1st and 2nd Centuries AD) in Southern Italy. Am. J. Phys. Anthropol. 139 (4), 572–583.
Curtis, M.J., Beaumont, J., Elamin, F., Wilson, A.S., Koon, H.E., 2022. Method of micro-sampling human dentine collagen for stable isotope analysis. Rapid Commun. Mass Spectrom. 36 (13), e9305.
Davis, K.A., Mountain, R.V., Pickett, O.R., Den Besten, P.K., Bidlack, F.B., Dunn, E.C., 2020. Teeth as potential new tools to measure early-life adversity and subsequent mental health risk: an interdisciplinary review and conceptual model. Biol. Psychiatry 87 (6), 502–513.
de Vareilles, A., Pelling, R., Woodbridge, J., Fyfe, R., 2021. Archaeology and agriculture: plants, people, and past land-use. Trends Ecol. Evol. 36 (10), 943–954.
Dean, M.C., 1987. Growth layers and incremental markings in hard tissues; a review of the literature and some preliminary observations about enamel structure in *Paranthropus boisei*. J. Hum. Evol. 16 (2), 157–172.
Dean, M.C., 2000. Progress in understanding hominoid dental development. J. Anat. 197 (1), 77–101.
Dean, M.C., 2006. Tooth microstructure tracks the pace of human life-history evolution. Proc. R. Soc. Lond. B: Biol. Sci. 273 (1603), 2799–2808.
Dean, M.C., 2009. Extension rates and growth in tooth height of modern human and fossil hominin canines and molars. Comparative Dental Morphology. Karger Publishers, pp. 68–73.
Dean, M.C., 2010. Retrieving chronological age from dental remains of early fossil hominins to reconstruct human growth in the past. Philos. Trans. R. Soc. Lond. B: Biol. Sci. 365 (1556), 3397–3410.
Dean, M.C., 2016. Measures of maturation in early fossil hominins: events at the first transition from australopiths to early Homo. Philos. Trans. R. Soc. Lond. B: Biol. Sci. 371 (1698), 20150234.
Dean, M.C., 2017. How the microstructure of dentine can contribute to reconstructing developing dentitions and the lives of hominoids and hominins = Comment la microstructure de la dentine peut contribuer à reconstruire le développement dentaire et la vie des hominoïdes et homininés. Comptes Rendus Palevol 16 (5-6), 557–571.
Dean, M.C., 2019. Anders Retzius and the dental histologists of the mid-nineteenth century: their contribution to comparative anatomy, histology and anthropology. J. Hist. Dent. 62 (2), 58–97.
Dean, M.C., Cole, T.J., 2013. Human life history evolution explains dissociation between the timing of tooth eruption and peak rates of root growth. PloS ONE 8 (1), e54534.
Dean, M.C., Elamin, F., 2014. Parturition lines in modern human wisdom tooth roots: do they exist, can they be characterized and are they useful for retrospective determination of age at first reproduction and/or inter-birth intervals? Ann. Hum. Biol. 41 (4), 358–367.
Dean, M.C., Humphrey, L., Groom, A., Hassett, B., 2020. Variation in the timing of enamel formation in modern human deciduous canines. Arch. Oral. Biol., 104719
Dean, M.C., Leakey, M.G., Reid, D., Schrenk, F., 2001. Growth processes in teeth distinguish modern humans from Homo erectus and earlier hominins. Nature 414 (6864), 628.
Dean, M.C., Liversidge, H.M., 2015. Age estimation in fossil hominins: comparing dental development in early Homo with modern humans. Ann. Hum. Biol. 42 (4), 415–429.
Dean, M.C., Smith, B.H., 2009. Growth and development of the Nariokotome youth, KNM-WT 15000. In: Grine, F.E., Fleagle, J.G., Leakey, R.E. (Eds.), The first humans–origin and early evolution of the genus Homo. Springer, pp. 101–120.
Dean, M.C., Spiers, K.M., Garrevoet, J., Le Cabec, A., 2019. Synchrotron X-ray fluorescence mapping of Ca, Sr and Zn at the neonatal line in human deciduous teeth reflects changing perinatal physiology. Arch. Oral. Biol. 104, 90–102.
DeWitte, S.N., Stojanowski, C.M., 2015. The osteological paradox 20 years later: past perspectives, future directions. J. Archaeol. Res. 23 (4), 397–450.
Dodat, P.-J., Tacail, T., Albalat, E., Gómez-Olivencia, A., Couture-Veschambre, C., Holliday, T., Madelaine, S., Martin, J.E., Rmoutilova, R., Maureille, B., 2021. Isotopic calcium biogeochemistry of MIS 5 fossil vertebrate bones: application to the study of the dietary reconstruction of Regourdou 1 Neandertal fossil. J. Hum. Evol. 151, 102925.
Dunn, E.C., McLaughlin, K.A., Slopen, N., Rosand, J., Smoller, J.W., 2013. Developmental timing of child maltreatment and symptoms of depression and

suicidal ideation in young adulthood: results from the National Longitudinal Study of Adolescent Health. Depress Anxiety 30 (10), 955–964.
Dunn, E.C., Mountain, R.V., Davis, K.A., Shaffer, I., Smith, A.D., Roubinov, D.S., Den Besten, P., Bidlack, F.B., Boyce, W.T., 2022. Association Between Measures Derived From Children's Primary Exfoliated Teeth and Psychopathology Symptoms: Results From a Community-Based Study. Front. Dent. Med. 3, 803364.
Dunn, E.C., Soare, T.W., Raffeld, M.R., Busso, D.S., Crawford, K.M., Davis, K.A., Fisher, V.A., Slopen, N., Smith, A.D., Tiemeier, H., 2018. What life course theoretical models best explain the relationship between exposure to childhood adversity and psychopathology symptoms: recency, accumulation, or sensitive periods? Psychol. Med. 48 (15), 2562–2572.
Dunn, E.C., Soare, T.W., Zhu, Y., Simpkin, A.J., Suderman, M.J., Klengel, T., Smith, A.D., Ressler, K.J., Relton, C.L., 2019. Sensitive periods for the effect of childhood adversity on DNA methylation: results from a prospective, longitudinal study. Biol. Psychiatry 85 (10), 838–849.
Eckardt, H., Chenery, C., Booth, P., Evans, J.A., Lamb, A., Müldner, G., 2009. Oxygen and strontium isotope evidence for mobility in Roman Winchester. J. Archaeol. Sci. 36 (12), 2816–2825.
Elias, R.W., Hirao, Y., Patterson, C.C., 1982. The circumvention of the natural biopurification of calcium along nutrient pathways by atmospheric inputs of industrial lead. Geochim. Et. Cosmochim. Acta 46 (12), 2561–2580.
Evans, J.A., Pashley, V., Mee, K., Wagner, D., Parker Pearson, M., Fremondeau, D., Albarella, U., Madgwick, R., 2022. Applying lead (Pb) isotopes to explore mobility in humans and animals. PLoS One 17 (10), e0274831.
Field, Y., Boyle, E.A., Telis, N., Gao, Z., Gaulton, K.J., Golan, D., Yengo, L., Rocheleau, G., Froguel, P., McCarthy, M.I., 2016. Detection of human adaptation during the past 2000 years. Science 354 (6313), 760–764.
Filippelli, G.M., Laidlaw, M.A., Latimer, J.C., Raftis, R., 2005. Urban lead poisoning and medical geology: An unfinished story. GSA Today 15 (1), 4–11.
FitzGerald C. 1995. Tooth crown formation and the variation of enamel microstructural growth markers in modern humans [PhD Thesis]: University of Cambridge.
FitzGerald, C., 1998. Do enamel microstructures have regular time dependency? Conclusions from the literature and a large-scale study. J. Hum. Evol. 35 (4-5), 371–386.
FitzGerald, C., Hillson, S., 2009. Deciduous tooth growth in an ancient Greek infant cemetery. Comparative Dental Morphology. Karger Publishers, pp. 178–183.
FitzGerald, C., Rose, J.C., 2000. Reading between the lines: dental development and subadult age assessment using the microstructural growth markers of teeth. In: Katzenberg, M.A., Saunders, S.R. (Eds.), Biological Anthropology of the Human Skeleton, Second Edition. Wiley Liss, pp. 237–263.
FitzGerald, C., Saunders, S.R., 2005. Test of histological methods of determining chronology of accentuated striae in deciduous teeth. Am. J. Phys. Anthropol. 127 (3), 277–290.
FitzGerald, C., Saunders, S., Bondioli, L., Macchiarelli, R., 2006. Health of infants in an Imperial Roman skeletal sample: perspective from dental microstructure. Am. J. Phys. Anthropol. 130 (2), 179–189.
Fleming, R., 2009. Writing Biography at the Edge of History. Am. Hist. Rev. 114 (3), 606–614.
Fraser, A., Macdonald-Wallis, C., Tilling, K., Boyd, A., Golding, J., Davey Smith, G., Henderson, J., Macleod, J., Molloy, L., Ness, A., 2013. Cohort profile: the Avon Longitudinal Study of Parents and Children: ALSPAC mothers cohort. Int. J. Epidemiol. 42 (1), 97–110.
Gerbi, L., Austin, C., Pedretti, N.F., McRae, N., Amarasiriwardena, C.J., Mercado-García, A., Torres-Olascoaga, L.A., Tellez-Rojo, M.M., Wright, R.O., Arora, M., 2022. Biomarkers of maternal lead exposure during pregnancy using micro-spatial child deciduous dentine measurements. Environ. Int. 169, 107529.
Germine, L., Dunn, E.C., McLaughlin, K.A., Smoller, J.W., 2015. Childhood adversity is associated with adult theory of mind and social affiliation, but not face processing. PloS One 10 (6), e0129612.
Glezen, W.P., 2003. Effect of maternal antibodies on the infant immune response. Vaccine 21 (24), 3389–3392.
Goodman, A.H., Armelagos, G.J., 1989. Infant and childhood morbidity and mortality risks in archaeological populations. World Archaeol. 21 (2), 225–243.
Goodman, A.H., Brooke Thomas, R., Swedlund, A.C., Armelagos, G.J., 1988. Biocultural perspectives on stress in prehistoric, historical, and contemporary population research. Am. J. Phys. Anthropol. 31 (S9), 169–202.
Goodman, A.H., Rose, J.C., 1990. Assessment of systemic physiological perturbations from dental enamel hypoplasias and associated histological structures. Am. J. Phys. Anthropol. 33 (S11), 59–110.
Gowland, R.L., 2015. Entangled lives: implications of the developmental origins of health and disease hypothesis for bioarchaeology and the life course. Am. J. Phys. Anthropol. 158 (4), 530–540.
Gowland, R., Halcrow, S., 2019. The Mother-infant Nexus in Anthropology: Small Beginnings, Significant Outcomes. Springer.
Grossmann, T., Johnson, M.H., 2007. The development of the social brain in human infancy. Eur. J. Neurosci. 25 (4), 909–919.
Guatelli-Steinberg, D., 2016. What Teeth Reveal about Human Evolution. Cambridge University Press.
Guatelli-Steinberg, D., Floyd, B.A., Dean, M.C., Reid, D.J., 2012. Enamel extension rate patterns in modern human teeth: two approaches designed to establish an integrated comparative context for fossil primates. J. Hum. Evol. 63 (3), 475–486.
Halcrow, S., 2020. Infants in the bioarchaeological past: Who cares? In: Gowland, R., Halcrow, S. (Eds.), The Mother-Infant Nexus in Anthropology: Small Beginnings, Significant Outcomes. Springer Cham, pp. 19–38.
Halcrow, S., Warren, R., Kushnick, G., Nowell, A., 2020. Care of Infants in the Past: Bridging evolutionary anthropological and bioarchaeological approaches. Evolut. Hum. Sci. 2.
Hardy, B.L., 2010. Climatic variability and plant food distribution in Pleistocene Europe: implications for Neanderthal diet and subsistence. Quat. Sci. Rev. 29 (5-6), 662–679.
Hare, D., Austin, C., Doble, P., Arora, M., 2011. Elemental bio-imaging of trace elements in teeth using laser ablation-inductively coupled plasma-mass spectrometry. J. Dent. 39 (5), 397–403.
Hawkes, K., Finlay, B.L., 2018. Mammalian brain development and our grandmothering life history. Physiol. Behav. 193, 55–68.
Hawks, J., Wang, E.T., Cochran, G.M., Harpending, H.C., Moyzis, R.K., 2007. Recent acceleration of human adaptive evolution. Proc. Natl. Acad. Sci. USA 104 (52), 20753–20758.
Heldstab, S.A., Isler, K., Burkart, J.M., van Schaik, C.P., 2019. Allomaternal care, brains and fertility in mammals: who cares matters. Behav. Ecol. Sociobiol. 73, 1–13.
Heldstab, S.A., van Schaik, C.P., Isler, K., 2016. Being fat and smart: a comparative analysis of the fat-brain trade-off in mammals. J. Hum. Evol. 100, 25–34.
Hillson, S., 2014. Cambridge. Tooth development in human evolution and bioarchaeology. Cambridge University Press.
Hillson, S., 2023. Cambridge. Dental anthropology. Cambridge University Press.
Hrdy, S.B., Burkart, J.M., 2020. The emergence of emotionally modern humans: implications for language and learning. Philos. Trans. R. Soc. B 375 (1803), 20190499.
Huda, T.F., Bowman, J., 1994. Variation in cross-striation number between striae in an archaeological population. Int. J. Osteoarchaeol. 4 (1), 49–52.
Humphrey, L.T., 2014. Isotopic and trace element evidence of dietary transitions in early life. Ann. Hum. Biol. 41 (4), 348–357.
Humphrey, L.T., Dean, M.C., Jeffries, T.E., Penn, M., 2008a. Unlocking evidence of early diet from tooth enamel. Proc. Natl. Acad. Sci. USA 105 (19), 6834–6839.
Humphrey, L.T., Dirks, W., Dean, M.C., Jeffries, T.E., 2008b. Tracking dietary transitions in weanling baboons (Papio hamadryas anubis) using strontium/calcium ratios in enamel. Folia Primatol. 79 (4), 197–212.
Humphrey, L.T., King, T., 2000. Childhood stress: a lifetime legacy. Anthropologie 38 (1), 33–49.
Jaouen, K., Villalba-Mouco, V., Smith, G.M., Trost, M., Leichliter, J., Lüdecke, T., Méjean, P., Mandrou, S., Chmeleff, J., Guiserix, D., et al., 2022. A Neandertal dietary conundrum: Insights provided by tooth enamel Zn isotopes from Gabasa, Spain. Proc. Natl. Acad. Sci. USA 119 (43), e2109315119.
Joannes-Boyau, R., Adams, J.W., Austin, C., Arora, M., Moffat, I., Herries, A.I., Tonge, M. P., Benazzi, S., Evans, A.R., Kullmer, O., et al., 2019. Elemental signatures of Australopithecus africanus teeth reveal seasonal dietary stress. Nature 572 (7767), 112–115.
Juster, R.-P., Bizik, G., Picard, M., Arsenault-Lapierre, G., Sindi, S., Trepanier, L., Marin, M.-F., Wan, N., Sekerovic, Z., Lord, C., 2011. A transdisciplinary perspective of chronic stress in relation to psychopathology throughout life span development. Dev. Psychopathol. 23 (3), 725–776.
Kajiyama, S., 1965. Total number of regular incremental lines (Regulare Parallelstreifen nach Asper) in the enamel of human permanent teeth. J. Nihon Univ. Sch. Dent. 39, 77–83.
Kamp, K.A., 2001. Where have all the children gone?: the archaeology of childhood. J. Archaeol. Method Theory 8, 1–34.
Kendall E., Beaumont J., and Millard A. 2020. The "weanling's dilemma" revisited: Evolving bodies of evidence and the problem of infant paleodietary interpretation.
Kenkel, W.M., Perkeybile, A.M., Carter, C.S., 2017. The neurobiological causes and effects of alloparenting. Dev. Neurobiol. 77 (2), 214–232.
Kierdorf, H., Witzel, C., Bocaege, E., Richter, T., Kierdorf, U., 2021. Assessment of physiological disturbances during pre-and early postnatal development based on microscopic analysis of human deciduous teeth from the Late Epipaleolithic site of Shubayqa 1 (Jordan). Am. J. Phys. Anthropol. 174 (1), 20–34.
Klein, O.D., Duverger, O., Shaw, W., Lacruz, R.S., Joester, D., Moradian-Oldak, J., Pugach, M.K., Wright, J.T., Millar, S.E., Kulkarni, A.B., 2017. Meeting report: a hard look at the state of enamel research. Int. J. Oral. Sci. 9 (11), e3.
Knudsen, E.I., 2004. Sensitive periods in the development of the brain and behavior. J. Cogn. Neurosci. 16 (8), 1412–1425.
Krachler, M., Rossipal, E., Micetic-Turk, D., 1999a. Concentrations of trace elements in sera of newborns, young infants, and adults. Biol. Trace Elem. Res. 68 (2), 121.
Krachler, M., Rossipal, E., Micetic-Turk, D., 1999b. Trace element transfer from the mother to the newborn—investigations on triplets of colostrum, maternal and umbilical cord sera. Eur. J. Clin. Nutr. 53 (6), 486–494.
Kramer, K.L., 2010. Cooperative breeding and its significance to the demographic success of humans. Annu. Rev. Anthropol. 39, 417–436.
Krapohl, E., Hannigan, L., Pingault, J.-B., Patel, H., Kadeva, N., Curtis, C., Breen, G., Newhouse, S., Eley, T., O'Reilly, P., 2017. Widespread covariation of early environmental exposures and trait-associated polygenic variation. Proc. Natl. Acad. Sci. USA 201707178.
Kubat, J., Nava, A., Bondioli, L., Dean, M.C., Zanolli, C., Bourgon, N., Bacon, A.-M., Demeter, F., Peripoli, B., Albert, R., et al., 2023. Dietary strategies of Pleistocene Pongo sp. and Homo erectus on Java (Indonesia). Nat. Ecol. Evol. 7, 279–289.
Kuzawa, C.W., Bragg, J.M., 2012. Plasticity in human life history strategy: implications for contemporary human variation and the evolution of genus Homo. Curr. Anthropol. 53 (S6), S369–S382.
Kuzawa, C.W., Chugani, H.T., Grossman, L.I., Lipovich, L., Muzik, O., Hof, P.R., Wildman, D.E., Sherwood, C.C., Leonard, W.R., Lange, N., 2014. Metabolic costs and evolutionary implications of human brain development. Proc. Natl. Acad. Sci. 111 (36), 13010–13015.

Lacruz, R.S., Hacia, J.G., Bromage, T.G., Boyde, A., Lei, Y., Xu, Y., Miller, J.D., Paine, M. L., Snead, M.L., 2012. The circadian clock modulates enamel development. J. Biol. Rhythms 27 (3), 237–245.
Larsen, C.S., 2015. Bioarchaeology: interpreting behavior from the human skeleton. Cambridge. Cambridge University Press.
Le Cabec, A., Dean, M.C., Begun, D.R., 2017. Dental development and age at death of the holotype of Anapithecus hernyaki (RUD 9) using synchrotron virtual histology. J. Hum. Evol. 108, 161–175.
Leeuwenhoek, A., 1677. Microscopical observations of the structure of teeth and other bones: made and communicated, in a Letter by Mr. Anthony Leeuwenhoeck. Philos. Trans. R. Soc. Lond. Ser. I 12, 1002–1003.
Leichliter, J.N., Lüdecke, T., Foreman, A.D., Duprey, N.N., Winkler, D.E., Kast, E.R., Vonhof, H., Sigman, D.M., Haug, G.H., Clauss, M., 2021. Nitrogen isotopes in tooth enamel record diet and trophic level enrichment: Results from a controlled feeding experiment. Chem. Geol. 563, 120047.
Leigh, S.R., 2001. Evolution of human growth. Evolut. Anthropol.: Issues, N., Rev. 10 (6), 223–236.
Lemmers, S.A., Dirks, W., Street, S.E., Ngoubangoye, B., Herbert, A., Setchell, J.M., 2021. Dental microstructure records life history events: a histological study of mandrills (Mandrillus sphinx) from Gabon. J. Hum. Evol. 158, 103046.
Leppänen, J.M., Nelson, C.A., 2009. Tuning the developing brain to social signals of emotions. Nat. Rev. Neurosci. 10 (1), 37–47.
Lewis, M.E., 2018. Children in bioarchaeology: Methods and interpretations. In: Katzenberg, M.A., Grauer, A.L. (Eds.), Biological anthropology of the human skeleton. John Wiley & Sons, pp. 117–144.
Li, Q., Nava, A., Reynard, L.M., Thirlwall, M., Bondioli, L., Müller, W., 2022. Spatially-resolved Ca isotopic and trace element variations in human deciduous teeth record diet and physiological change. Environ. Archaeol. 27 (5), 474–483.
Li, Q., Thirlwall, M., Müller, W., 2016. Ca isotopic analysis of laser-cut microsamples of (bio) apatite without chemical purification. Chem. Geol. 422, 1–12.
Linscott, B., Pike, A.W., Angelucci, D.E., Cooper, M.J., Milton, J.S., Matias, H., Zilhão, J., 2023. Reconstructing Middle and Upper Paleolithic human mobility in Portuguese Estremadura through laser ablation strontium isotope analysis. Proc. Natl. Acad. Sci. USA 120 (20), e2204501120.
Liversidge, H.M., 2008. Timing of human mandibular third molar formation. Ann. Hum. Biol. 35 (3), 294–321.
Lorentz, K., Lemmers, S., Chrysostomou, C., Dirks, W., Zaruri, M., Foruzanfar, F., Sajjadi, S., 2019. Use of dental microstructure to investigate the role of prenatal and early life physiological stress in age at death. J. Archaeol. Sci. 104, 85–96.
Lugli, F., Cipriani, A., Arnaud, J., Arzarello, M., Peretto, C., Benazzi, S., 2017. Suspected limited mobility of a Middle Pleistocene woman from Southern Italy: strontium isotopes of a human deciduous tooth. Sci. Rep. 7 (1), 1–8.
Lugli, F., Cipriani, A., Bruno, L., Ronchetti, F., Cavazzuti, C., Benazzi, S., 2022a. A strontium isoscape of Italy for provenance studies. Chem. Geol. 587, 120624.
Lugli, F., Nava, A., Sorrentino, R., Vazzana, A., Bortolini, E., Oxilia, G., Silvestrini, S., Nannini, N., Bondioli, L., Fewlass, H., 2022b. Tracing the mobility of a Late Epigravettian (~ 13 ka) male infant from Grotte di Pradis (Northeastern Italian Prealps) at high-temporal resolution. Sci. Rep. 12 (1), 1–13.
Lupien, S.J., McEwen, B.S., Gunnar, M.R., Heim, C., 2009. Effects of stress throughout the lifespan on the brain, behaviour and cognition. Nat. Rev. Neurosci. 10 (6), 434–445.
Macchiarelli, R., Bondioli, L., Debénath, A., Mazurier, A., Tournepiche, J.-F., Birch, W., Dean, M.C., 2006. How Neanderthal molar teeth grew. Nature 444 (7120), 748.
Mahoney, P., 2011. Human deciduous mandibular molar incremental enamel development. Am. J. Phys. Anthropol. 144 (2), 204–214.
Mahoney, P., 2012. Incremental enamel development in modern human deciduous anterior teeth. Am. J. Phys. Anthropol. 147 (4), 637–651.
Mahoney, P., 2015. Dental fast track: prenatal enamel growth, incisor eruption, and weaning in human infants. Am. J. Phys. Anthropol. 156 (3), 407–421.
Mahoney, P., McFarlane, G., Loch, C., White, S., Floyd, B., Dunn, E.C., Pitfield, R., Nava, A., Guatelli-Steinberg, D., 2022. Dental biorhythm is associated with adolescent weight gain. Commun. Med. 2 (1), 99.
Mahoney, P., McFarlane, G., Smith, B.H., Miszkiewicz, J.J., Cerrito, P., Liversidge, H., Mancini, L., Dreossi, D., Veneziano, A., Bernardini, F., et al., 2021. Growth of neanderthal infants from krapina (120–130 ka). Croat. Proc. R. Soc. B 288, 20212079.
Mahoney, P., Miszkiewicz, J.J., Chapple, S., Le Luyer, M., Schlecht, S.H., Stewart, T.J., Griffiths, R.A., Deter, C., Guatelli-Steinberg, D., 2018. The biorhythm of human skeletal growth. J. Anat. 232, 26–38.
Mahoney, P., Miszkiewicz, J.J., Pitfield, R., Schlecht, S.H., Deter, C., Guatelli-Steinberg, D., 2016. Biorhythms, deciduous enamel thickness, and primary bone growth: a test of the Havers-Halberg Oscillation hypothesis. J. Anat. 228, 919–928.
Mahoney, P., Miszkiewicz, J.J., Pitfield, R., Deter, C., Guatelli-Steinberg, D., 2017. Enamel biorhythms of humans and great apes: the Havers-Halberg Oscillation hypothesis reconsidered. J. Anat. 230, 272–281.
Maret, W., 2022. The quintessence of metallomics: a harbinger of a different life science based on the periodic table of the bioelements. Metallomics 14 (8).
Martin, J., Ringen, E., Duda, P., Jaeggi, A., 2020. Harsh environments promote alloparental care across human societies. Proc. R. Soc. B 287 (1933), 20200758.
Massler, M., Schour, I., 1946. Growth of the child and the calcification pattern of the teeth. Am. J. Orthod. Oral. Surg. 32 (9), 495–517.
McEwen, B.S., 2003. Early life influences on life-long patterns of behavior and health. Ment. Retard. Dev. Disabil. Res. Rev. 9 (3), 149–154.
McEwen, B.S., 2012. Brain on stress: how the social environment gets under the skin. Proc. Natl. Acad. Sci. USA 109 (supplement_2), 17180–17185.
McFarlane, G., Guatelli-Steinberg, D., Loch, C., White, S., Bayle, P., Floyd, B., Pitfield, R., Mahoney, P., 2020. An inconstant biorhythm: the changing pace of Retzius periodicity in human permanent teeth. Am. J. Phys. Anthropol. 175 (1), 172–186.
McFarlane, G., Loch, C., Guatelli-Steinberg, D., Bayle, P., Le Luyer, M., Sabel, N., Nava, A., Floyd, B., Skinner, M., White, S., et al., 2021. Enamel daily secretion rates of deciduous molars from a global sample of children. Arch. Oral. Biol. 132, 105290.
Miller, M.J., Dong, Y., Pechenkina, K., Fan, W., Halcrow, S.E., 2020. Raising girls and boys in early China: Stable isotope data reveal sex differences in weaning and childhood diets during the eastern Zhou era. Am. J. Phys. Anthropol. 172 (4), 567–585.
Montgomery, J., 2010. Passports from the past: Investigating human dispersals using strontium isotope analysis of tooth enamel. Ann. Hum. Biol. 37 (3), 325–346.
Müller, W., Anczkiewicz, R., 2016. Accuracy of laser-ablation (LA)-MC-ICPMS Sr isotope analysis of (bio) apatite–a problem reassessed. J. Anal. At. Spectrom. 31 (1), 259–269.
Müller, W., Eggins, S., 2003. In-situ isotopic and trace elemental analysis of teeth by LA-(MC)ICPMS. Geochim. Et. Cosmochim. Acta 67, A312.
Müller, W., Fricke, H., Halliday, A.N., McCulloch, M.T., Wartho, J.A., 2003. Origin and migration of the alpine iceman. Science 302, 862–866.
Müller, W., Nava, A., Evans, D., Rossi, P.F., Alt, K.W., Bondioli, L., 2019. Enamel mineralization and compositional time-resolution in human teeth evaluated via histologically-defined LA-ICPMS profiles. Geochim. Et. Cosmochim. Acta 255, 105–126.
Müller, W., Shelley, M., Miller, P., Broude, S., 2009. Initial performance metrics of a new custom-designed ArF excimer LA-ICPMS system coupled to a two-volume laser-ablation cell. J. Anal. At. Spectrom. 24, 209–214.
Müller W, Lugli F, McCormack J, Evans, D. Anczkiewicz, R Bondioli, L Nava, A. in press. Human Life Histories. In: Treatise on Geochemistry 3rd edition.
Nanci, A., 2007. Ten Cate's oral histology: development, structure, and function. Elsevier Health Sciences.
Nava, A., 2024. Understanding the maternal-infant nexus from dental histology and high-resolution compositional biogeochemistry: implications for bioarchaeological research. Bull. Et. Mémoires De. la Soci. été D. 'Anthropol. De. Paris 36 (1).
Nava, A., Bondioli, L., Coppa, A., Dean, M.C., Rossi, P.F., Zanolli, C., 2017a. New regression formula to estimate the prenatal crown formation time of human deciduous central incisors derived from a roman imperial sample (Velia, Salerno, I-II cent. CE). PloS ONE 12 (7), e0180104.
Nava, A., Coppa, A., Coppola, D., Mancini, L., Dreossi, D., Zanini, F., Bernardini, F., Tuniz, C., Bondioli, L., 2017b. Virtual histological assessment of the prenatal life history and age at death of the Upper Paleolithic fetus from Ostuni (Italy). Sci. Rep. 7 (1), 9427.
Nava, A., Frayer, D.W., Bondioli, L., 2019. Longitudinal analysis of the microscopic dental enamel defects of children in the Imperial Roman community of Portus Romae (necropolis of Isola Sacra, 2nd to 4th century CE, Italy). J. Archaeol. Sci.: Rep. 23, 406–415.
Nava, A., Lugli, F., Romandini, M., Badino, F., Evans, D., Gregorio O, H.H.A., Arrighi, S., Bortolini, E., Delpiano, D., et al., 2020. Early life of Neanderthals. Proc. Natl. Acad. Sci. USA 117 (46), 28719–28726.
Navarrete, A., Van Schaik, C.P., Isler, K., 2011. Energetics and the evolution of human brain size. Nature 480 (7375), 91–93.
Needleman, H.L., Gunnoe, C., Leviton, A., Reed, R., Peresie, H., Maher, C., Barrett, P., 1979. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. N. Engl. J. Med. 300 (13), 689–695.
Newham, E., Naji, S., 2022. Identifying life-history events in dental cementum: a literature. In: Naji, S., Rendu, W., Gourichon, L. (Eds.), Dental Cementum in Anthropology. Cambridge: Cambridge University Press, p. 155.
Obtel, N., Le Cabec, A., Nguyen, T.N., Giabicani, E., Van Malderen, S.J., Garrevoet, J., Percot, A., Paris, C., Dean, C., Hadj-Rabia, S., 2022. Impact of claudin-10 deficiency on amelogenesis: Lesson from a HELIX tooth. Ann. N. Y. Acad. Sci. 1516 (1), 197–211.
Olejniczak, A.J., Smith, T.M., Feeney, R.N., Macchiarelli, R., Mazurier, A., Bondioli, L., Rosas, A., Fortea, J., de la Rasilla, M., Garcia-Tabernero, A., 2008. Dental tissue proportions and enamel thickness in Neandertal and modern human molars. J. Hum. Evol. 55 (1), 12–23.
Page, A.E., Thomas, M.G., Smith, D., Dyble, M., Viguier, S., Chaudhary, N., Salali, G.D., Thompson, J., Mace, R., Migliano, A.B., 2019. Testing adaptive hypotheses of alloparenting in Agta foragers. Nat. Hum. Behav. 3 (11), 1154–1163.
Pederzani, S., Britton, K., 2019. Oxygen isotopes in bioarchaeology: Principles and applications, challenges and opportunities. Earth-Sci. Rev. 188, 77–107.
Peek, S., Clementz, M.T., 2012. Sr/Ca and Ba/Ca variations in environmental and biological sources: a survey of marine and terrestrial systems. Geochim. Et. Cosmochim. Acta 95, 36–52.
Peripoli, B., Gigante, M., Mahoney, P., McFarlane, G., Coppa, A., Lugli, F., Lauria, G., Bondioli, L., Sconzo, P., Sineo, L., et al., 2023. Exploring prenatal and neonatal life history through dental histology in infants from the Phoenician necropolis of Motya (7th–6th century BCE). J. Archaeol. Sci.: Rep. 49, 104024.
Perrone, V., Gocha, T.P., Randolph-Quinney, P., Procopio, N., 2022. Tooth cementum annulation: a literature review. Forensic Sci. 2 (3), 516–550.
Price, T.D., Swick, R.W., Chase, E.P., 1986. Bone chemistry and prehistoric diet: strontium studies of laboratory rats. Am. J. Phys. Anthropol. 70 (3), 365–375.
Prowse, T.L., Saunders, S.R., Schwarcz, H.P., Garnsey, P., Macchiarelli, R., Bondioli, L., 2008. Isotopic and dental evidence for infant and young child feeding practices in an imperial Roman skeletal sample. Am. J. Phys. Anthropol. 137 (3), 294–308.
Quade, L., Chazot, P.L., Gowland, R., 2021. Desperately seeking stress: A pilot study of cortisol in archaeological tooth structures. Am. J. Phys. Anthropol. 174 (3), 532–541.

Rebay-Salisbury, K., Pany-Kucera, D., 2020. Ages and Abilities: The Stages of Childhood and their Social Recognition in Prehistoric Europe and Beyond. Archaeopress Publishing Ltd.
Retzius, A., 1837. Bemerkungen liber den inneren Bau der Zähne mit besonderer Berücksichtigung auf den im Zahnknochen vorkommenden Röhrenbau. Archiv für. Anat., Physiol. Wiss. Med. 4, 486–571.
Richards, M.P., Fuller, B.T., Hedges, R.E.M., 2001. Sulphur isotopic variation in ancient bone collagen from Europe: implications for human palaeodiet, residence mobility, and modern pollutant studies. Earth Planet. Sci. Lett. 191 (3-4), 185–190.
Robson, S., Van Schaik, C., Hawkes, K., 2006. The derived features of human life history. In: Hawkes, K., Paine, R.R. (Eds.), The Evolution of Human Life History. School of American Research Advanced Seminar Series, Santa Fe, New Mexico.
Robson, S.L., Wood, B., 2008. Hominin life history: reconstruction and evolution. J. Anat. 212 (4), 394–425.
Rosas, A., Ríos, L., Estalrrich, A., Liversidge, H., García-Tabernero, A., Huguet, R., Cardoso, H., Bastir, M., Lalueza-Fox, C., de la Rasilla, M., et al., 2017. The growth pattern of Neandertals, reconstructed from a juvenile skeleton from El Sidrón (Spain). Science 357 (6357), 1282–1287.
Rossipal, E., Krachler, M., Li, F., Micetic-Turk, D., 2000. Investigation of the transport of trace elements across barriers in humans: studies of placental and mammary transfer. Acta Paediatr. 89 (10), 1190–1195.
Sabel, N., Johansson, C., Kühnisch, J., Robertson, A., Steiniger, F., Norén, J.G., Klingberg, G., Nietzsche, S., 2008. Neonatal lines in the enamel of primary teeth—a morphological and scanning electron microscopic investigation. Arch. Oral. Biol. 53 (10), 954–963.
Salazar, P., Villaseca, P., Cisternas, P., Inestrosa, N.C., 2021. Neurodevelopmental impact of the offspring by thyroid hormone system-disrupting environmental chemicals during pregnancy. Environ. Res. 200, 111345.
Sanders, A.P., Saland, J.M., Wright, R.O., Satlin, L., 2018. Perinatal and childhood exposure to environmental chemicals and blood pressure in children: a review of literature 2007–2017. Pediatr. Res. 84 (2), 165–180.
Scheinost, D., Kwon, S.H., Lacadie, C., Sze, G., Sinha, R., Constable, R.T., Ment, L.R., 2016. Prenatal stress alters amygdala functional connectivity in preterm neonates. NeuroImage: Clin. 12, 381–388.
Schildroth, S., Bauer, J.A., Friedman, A., Austin, C., Coull, B.A., Placidi, D., White, R.F., Smith, D., Wright, R.O., Lucchini, R.G., 2023. Early life manganese exposure and reported attention-related behaviors in Italian adolescents. Environ. Epidemiol. 7 (6), e274.
Schour, I., 1936. The Neonatal Line in the enamel and dentin of the human deciduous teeth and first permanent molar. J. Am. Dent. Assoc. (1922) 23(10) (1946-1955).
Schour, I., Massler, M., 1937. Rate and gradient of growth in human deciduous teeth with special reference to neonatal ring. J. Dent. Res 16, 349–350.
Schour, I., Massler, M., 1940. Studies In tooth development: the growth pattern of human teeth part II. J. Am. Dent. Assoc. 27 (12), 1918–1931.
Schour, I., Poncher, H.G., 1937. Rate of apposition of enamel and dentin, measured by the effect of acute fluorosis. Am. J. Dis. Child. 54 (4), 757–776.
Schultz, M., Carli-Thiele, P., Schmidt-Schultzf, T.H., Kierdorf, U., Kierdorf, H., Teegen, W.-R., Kreutz, K., 1998. Enamel hypoplasias in archaeological skeletal remains. In: Alt, K.W., Rosing, F.W., Teschler-Nicola, M. (Eds.), Dental Anthropology. Berlin: Springer, pp. 293–311.
Schwarcz, H.P., Schoeninger, M.J., 2012. Stable isotopes of carbon and nitrogen as tracers for paleo-diet reconstruction, Vol I. Handbook of Environmental Isotope Geochemistry, pp. 725–742.
Schwartz, G.T., Reid, D.J., Dean, M.C., Zihlman, A.L., 2006. A Faithful Record of Stressful Life Events Recorded in the Dental Developmental Record of a Juvenile Gorilla. Int. J. Primatol. 27 (4), 1201–1219.
Sellen, D.W., 2009. Evolution of Human Lactation and Complementary Feeding: Implications for Understanding Contemporary Cross-cultural Variation. In: Goldberg, G., Prentice, A., Prentice, A., Filteau, S., Simondon, K. (Eds.), Breast-Feeding: Early Influences on Later Health. Springer Netherlands, Dordrecht, pp. 253–282.
Seow, W.K., 1992. Dental enamel defects in low birth weight children. J. Paleopathol. Monogr. Publ. 2, 321–330.
Šešelj, M., 2017. Brief communication: an analysis of dental development in Pleistocene Homo using skeletal growth and chronological age. Am. J. Phys. Anthropol. 163 (3), 531–541.
Shannon, R., 1976. Revised effective ionic radii and systematic studies of interatomic distances in halides and chalcogenides. Acta Crystallogr. Sect. A: Cryst. Phys., Diffr., Theor. Gen. Crystallogr. 32 (5), 751–767.
Shellis, R., 1984. Variations in growth of the enamel crown in human teeth and a possible relationship between growth and enamel structure. Arch. Oral. Biol. 29 (9), 697–705.
Simpson, S.W., 1999. Reconstructing patterns of growth disruption from enamel micro-structure. In: Hoppa, R.D., FitzGerald, C. (Eds.), Human growth in the past: studies from bones and teeth. Cambridge University Press, Cambridge, pp. 241–263.
Sipovac, M., Petrovic, B., Amzirkov, M., Stefanovic, S., 2023. Enamel incremental markings in the deciduous teeth of children from the Early Bronze and modern ages. Arch. Oral. Biol. 148, 105635.
Skinner, M., Goodman, A.H., 1992. Skeletal biology of past peoples: research methods. Anthropological uses of developmental defects of enamel. Wiley-Liss p, New York, pp. 153–174.
Smith, B.H., 1991. Dental development and the evolution of life history in Hominidae. Am. J. Phys. Anthropol. 86 (2), 157–174.
Smith, B.H., 1992. Life history and the evolution of human maturation. Evolut. Anthropol.: Issues, N., Rev. 1 (4), 134–142.
Smith, B.H., 2004. The paleontology of growth and development. Evolut. Anthropol. Issues N. Rev. 13 (6), 239–241.
Smith, T.M., 2006. Experimental determination of the periodicity of incremental features in enamel. J. Anat. 208 (1), 99–113.
Smith, T.M., 2013. Teeth and human life-history evolution. Annu. Rev. Anthropol. 42, 191–208.
Smith, T.M., Arora, M., Bharatiya, M., Dirks, W., Austin, C., 2023. Elemental models of primate nursing and weaning revisited. Am. J. Biol. Anthropol. 180 (1), 216–223.
Smith, T.M., Austin, C., Ávila, J.N., Dirks, W., Green, D.R., Williams, I.S., Arora, M., 2022. Permanent signatures of birth and nursing initiation are chemically recorded in teeth. J. Archaeol. Sci. 140, 105564.
Smith, T.M., Austin, C., Green, D.R., Joannes-Boyau, R., Bailey, S., Dumitriu, D., Fallon, S., Grün, R., James, H.F., Moncel, M.-H., 2018a. Wintertime stress, nursing, and lead exposure in Neanderthal children. Sci. Adv. 4 (10), eaau9483.
Smith, T.M., Austin, C., Green, D.R., Joannes-Boyau, R., Bailey, S., Dumitriu, D., Fallon, S., Grün, R., James, H.F., Moncel, M.-H., et al., 2018b. Wintertime stress, nursing, and lead exposure in Neanderthal children. Sci. Adv. 4 (10).
Smith, T.M., Cook, L., Dirks, W., Green, D.R., Austin, C., 2021. Teeth reveal juvenile diet, health and neurotoxicant exposure retrospectively: what biological rhythms and chemical records tell us. BioEssays 2000298.
Smith, T.M., Martin, L.B., Reid, D.J., de Bonis, L., Koufos, G.D., 2004. An examination of dental development in Graecopithecus freybergi (= Ouranopithecus macedoniensis). J. Hum. Evol. 46 (5), 551–577.
Smith, T.M., Tafforeau, P., 2008. New visions of dental tissue research: tooth development, chemistry, and structure. Evolut. Anthropol.: Issues, N., Rev. 17 (5), 213–226.
Stearns, S.C., Rodrigues, A.M., 2020. On the use of "life history theory" in evolutionary psychology. Evol. Hum. Behav. 41 (6), 474–485.
Stefanović, S., Petrović, B., Porčić, M., Penezić, K., Pendić, J., Dimitrijević, V., Živaljević, I., Vuković, S., Jovanović, J., Kojić, S., 2019. Bone spoons for prehistoric babies: detection of human teeth marks on the Neolithic artefacts from the site Grad-Starčevo (Serbia). PloS One 14 (12), e0225713.
Stein, D.J., Koen, N., Donald, K., Adnams, C.M., Koopowitz, S., Lund, C., Marais, A., Myers, B., Roos, A., Sorsdahl, K., 2015. Investigating the psychosocial determinants of child health in Africa: the Drakenstein Child Health Study. J. Neurosci. Methods 252, 27–35.
Tacail, T., Thivichon-Prince, B., Martin, J.E., Charles, C., Viriot, L., Balter, V., 2017. Assessing human weaning practices with calcium isotopes in tooth enamel. Proc. Natl. Acad. Sci. USA 114 (24), 6268–6273.
Tagiguchi, H., 1966. Chronologic relationship of human tooth crown formation. J. Nihon Univ. Sch. Dent. 40, 391–397.
Teivens, A., Mornstad, H., Norén, J.G., Gidlund, E., 1996. Enamel incremental lines as recorders for disease in infancy and their relation to the diagnosis of SIDS. Forensic Sci. Int. 81 (2), 175–183.
Towle, I., Loch, C., 2024. Variation in enamel prism size in primate molars. Arch. Oral. Biol. 160, 105895.
Tsutaya, T., 2020. Blurred time resolution of tooth dentin serial sections. Am. J. Phys. Anthropol. 173 (4), 748–759.
Van Schaik, C.P., Burkart, J.M., 2010. Mind the gap: Cooperative breeding and the evolution of our unique features. In: Kappeler, P., Silk, J. (Eds.), Mind the gap: Tracing the origins of human universals. Springer, Berlin, Heidelberg, pp. 477–496.
Walker, R., Hill, K., Burger, O., Hurtado, A.M., 2006. Life in the slow lane revisited: Ontogenetic separation between chimpanzees and humans. Am. J. Phys. Anthropol. 129 (4), 577–583.
Wang, G., Chen, Z., Bartell, T., Wang, X., 2014. Early life origins of metabolic syndrome: the role of environmental toxicants. Curr. Environ. Health Rep. 1, 78–89.
Witzel, C., 2014. Echoes from birth–Mutual benefits for physical and forensic anthropology by applying increment counts in enamel of deciduous teeth for aging. Anthropol. Anz. 71 (1-2), 87–103.
Witzel, C., Kierdorf, U., Schultz, M., Kierdorf, H., 2008. Insights from the inside: histological analysis of abnormal enamel microstructure associated with hypoplastic enamel defects in human teeth. Am. J. Phys. Anthropol. 136 (4), 400–414.
Wood, J.W., Milner, G.R., Harpending, H.C., Weiss, K.M., Cohen, M.N., Eisenberg, L.E., Hutchinson, D.L., Jankauskas, R., Cesnys, G., Česnys, G., 1992. The osteological paradox: problems of inferring prehistoric health from skeletal samples [and comments and reply]. Curr. Anthropol. 33 (4), 343–370.
World Health Organization, W., 2023. Guideline for complementary feeding of infants and young children 6-23 months of age. World Health Organization, Geneva.
Żądzińska, E., Lorkiewicz, W., Kurek, M., Borowska-Strugińska, B., 2015. Accentuated lines in the enamel of primary incisors from skeletal remains: a contribution to the explanation of early childhood mortality in a medieval population from Poland. Am. J. Phys. Anthropol. 157 (3), 402–410.
Zandi, M., Shokri, A., Malekzadeh, H., Amini, P., Shafiey, P., 2015. Evaluation of third molar development and its relation to chronological age: a panoramic radiographic study. Oral. Maxillofac. Surg. 19, 183–189.
Zazzo, A., Bendrey, R., Vella, D., Moloney, A., Monahan, F., Schmidt, O., 2012. A refined sampling strategy for intra-tooth stable isotope analysis of mammalian enamel. Geochim. Et. Cosmochim. Acta 84, 1–13.
Zheng, L., Ehardt, L., McAlpin, B., About, I., Kim, D., Papagerakis, S., Papagerakis, P., 2014. The tick tock of odontogenesis. Exp. Cell Res. 325 (2), 83–89.
Zheng, L., Seon, Y.J., Mourão, M.A., Schnell, S., Kim, D., Harada, H., Papagerakis, S., Papagerakis, P., 2013. Circadian rhythms regulate amelogenesis. Bone 55 (1), 158–165.
Zohar, I., Alperson-Afil, N., Goren-Inbar, N., Prévost, M., Tütken, T., Sisma-Ventura, G., Hershkovitz, I., Najorka, J., 2022. Evidence for the cooking of fish 780,000 years ago at Gesher Benot Ya'aqov, Israel. Nat. Ecol. Evol. 6 (12), 2016–2028.