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Tooth Growth in Ancient and Modern Times Inferred from Perikymata Growth Intervals; Modeled Statistically

Clifford Qualls[1], Maria Antonietta Costa[2], Mike Paffett[3] and Otto Appenzeller[4]

[1]Department of Mathematics and Statistics, University of New Mexico, Albuquerque, NM, USA
[2]Institute of Archaeological Research and Museum, Catholic University of the North, R. P. Gustavo Le Paige S.J., Chile
[3]Fluorescence Microscopy Facility, Cancer Research and Treatment Center, Health Sciences Center, University of New Mexico, Albuquerque, NM, USA
[4]New Mexico Museum of Natural History and Science, New Mexico Health Enhancement and Marathon Clinics Research Foundation, Albuquerque, NM, USA

Abstract

Tooth growth is essential to health and survival. In humans the growth rate can be inferred from the width of perikymata growth intervals. We hypothesized that in ancient times teeth grew faster than in modern humans. We measured the intervals between perikymata ridges on the surfaces of teeth and in thin sections of molars (which we used as standards) in ancient, prehistoric and modern humans. We compared statistically the results from ancient and modern specimens and assessed the impact of dietary factors and sociality on tooth growth. We found that ancient teeth grew faster than modern teeth (wider intervals) because of environmental, nutritional and life style influences. This apparently conferred evolutionary advantages for human survival. Our results gleaned from combining measurements of sections of teeth with modeling of web-available images suggest that life styles of modern humans have lead to smaller teeth.

Keywords: Tooth growth; Diet; Prehistoric times; Modern times; Sociality connectivity; Faster tooth growth; Smaller teeth modern times

Introduction

Perikymata ridges are found on the enamel of human teeth; they mark the layered growth of enamel that occurs over a period of ~7-11 days [1]. These ridges are also found on the teeth of archaic humans. However the evolutionary dividing lines that separate modern humans from archaic Homo sapiens and archaic humans from Homo erectus remain unclear [2]. Linear enamel hypoplasias (LEH) are irregularities in the usually regular spacing of the perikymata grooves and are indicators of physiological stress or disease [3]. We compared, in histological sections of human third molars, the perikymata growth intervals (striae of Retzius) in teeth from the San Pedro culture (~1500 years ago) [4] with similar sections obtained from contemporaneous molars (10-40 years ago). We then turned to, on line available and X-ray images, of teeth belonging to South American cultures (~1500 before present, BP), ancient Egyptians (2000-3000, BP) the Iceman's teeth (5300, BP), Denisovan (41,000-50,000 BP), Neanderthals (~160,000, PB), Homo floresensis (60,000-100,000 BP), as well as images of modern contemporaneous human teeth and measured the perikymata growth intervals in these images. Finally we compared statistically the measurements obtained from images with those obtained from sections (our gold standard).

We hypothesized that because of different life styles (diet, stress, sociology and lack of artificial illumination) perikymata growth intervals would be wider in teeth from ancient times than in contemporaneous teeth.

Materials and Methods

Each tooth was stabilized with copper wire and sectioned with a diamond bladed rock saw. The sections were reduced in thickness to ~40 μm using Carborundum and embedded in a plastic block using Epo-Tech 301 resin (Epoxy Technology, inc, Billerca MA, USA) and finally glued to a glass cover slide.

Transmitted bright field microscopy of perikymata interval (PI) measurements

Thin tooth sections from either (old (~1500 years, n=8) or (modern ~10-40 years, n=4) teeth were examined using transmitted bright field image acquisition (Figure 1a and 1b). All images were acquired with a 10X/0.30NA plan neofluar lens on a Zeiss Axioskop 2 MOT upright microscope outfitted with a Zeiss AxioCamHR color camera controlled via AxioVisionSE imaging software. Flat-field corrected and white-balanced images were collected for off-line perikymata interval (PI) measurements in which PIs (n=8/tooth section) were measured by a calibrated (0.1063 microns/pixel) digital micrometer in a consistent work flow from crown to root. Individual PI measurements are given in microns and summary data expressed as mean ± S.D.

An arbitrary scale from 1-10 was assigned for dietary factors (reported on the web such as the amount and type of grain, meat and fish and refined foods consumed) and sociality defined by warfare and reported village life styles and based on smart 'phone and computer use in modern societies as the degree of connectivity compared to that in ancient cultures (Table 1).

Ages of teeth: Egyptian teeth (2000-3000 years ago; the Iceman 5500 years ago) before present (5000-160,000 years ago) and modern 600 to 10 years ago.

Dietary factors: In images of molars: Loaves of bread, fruits, vegetables, beef, figs and fine wine 10. Prehistoric Iceman: ibex and venison with a high percentage of fat (his last meal) 9. Denisovans: vegetarian diets 7. Homo **Floresensis:** fish, frogs, snakes, tortoises, birds, and rodents 7. Neanderthal: large herbivorous mammals such as mammoths and woolly rhinoceros 7.

***Corresponding author:** Appenzeller O, New Mexico Health Enhancement and Marathon Clinics Research Foundation and New Mexico Museum of Natural History and Science, Albuquerque, NM, USA, Tel: 505 822 0269; E-mail: ottoarun12@aol.com

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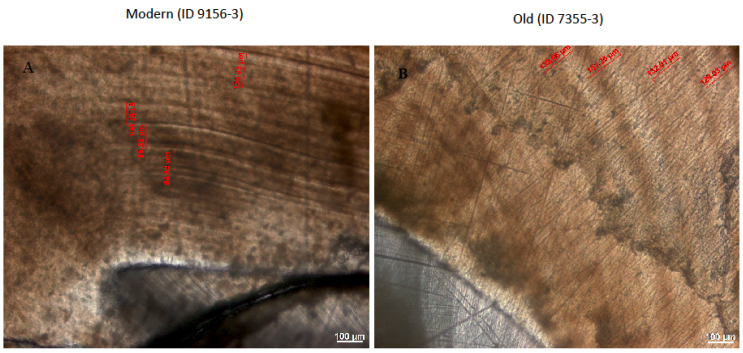

Figure 1: (a) Modern tooth section (ID 9156-3). (b) Old tooth section (ID 7355-3).

Epoch	Ages Teeth	N Teeth	Perikymata	Assigned values	
Images of Teeth				Diet	Sociality
Prehistoric					
	160 K	1	36	7	NA
	120 K	1	19	7	2
	45 K	1	20	7	2
	5 K	1	28	9	3
Historic					
	5.5 K	2	41	10	6
	3 K	2	41	9	6
	1.5 K	1	23	7	4
Modern					
	600 years	8	64	7	4
	30-50 years	1	20	4	10
Sections of Molars					
Historic					
	1.5 K	8	64	7	4
Modern					
	10-40 years	4	32	4	10

Table 1: Assigned values and ages of teeth, dietary factors and sociality in images and in measured perikymata intervals from sections.

Sociality: South American: village life, warfare 4. Prehistoric: Iceman, 3. Denisovan 2. Homo Floresensis: hunter gatherer-small bands, perhaps, cooperative hunting 2. Neanderthal: sharing food-sharing resources-collective hunting tool making 4. Modern humans: no longer making tools, community living, community rearing of offspring and high connectivity 10.

Tooth sections: South American village life AD 1500, warfare 4. Modern: community living, community rearing of offspring and high connectivity 10.

Dietary factors: San Pedro culture, South America: C3 foods such as potatoes and quinoa; no C4 such as maize 4 Modern: processed foods high in sodium and hydrogenated fats and low in fiber 7.

Permits and permissions

Archeological samples were donated by the Museo Arqueologico de San Pedro de Atacama, Universidad Catolica del Norte, Chile (letter dated March 26, 2003). Eight third molars from Coyo 3 cemetery were used for this study (# 13.236; 13.280; 13.318; 13.350; 13.363; 13.487; 13.608; 13.735). Four modern third molars donated by local dentist were used in this study. Prior to use they were destined for destruction and disposal. All experimental protocols were approved by: the Museo Arqueologico de San Pedro de Atacama, Universidad Catolica del Norte, Chile (letter dated March 26, 2003).

Statistical analyses

Since the measurements in the pictures were magnified relative to the direct measurements of the sections (our standard), we scaled the picture measurements to have the same variability as that of the sections. In addition, the mean measurement of the modern teeth should be the same in both the pictures and the sections; the resulting

linear transformation of the measurements in the pictures was y=1.29 + x/3.45 (Figure 2).

We computed perikymata interval ratios (old / modern measurements) in images and sections separately. The logarithm of ratios was used to symmetrize the skewed distributions of ratios. The variability (standard deviation) of logarithm of ratios in images was then scaled to the variability (standard deviation) in the sections expecting that the ratios of the images will not differ statistically from those of the sections (to be tested by t-test). These ratios (both in images and sections) will be used to test whether the perikymata intervals in old are larger than in modern teeth (to be tested by t-test of log-ratios with conversion of log means back to geometric means) (Figure 3).

The variability (standard deviation) of logarithm of ratios in images has been scaled to the standard deviation in sections showing that the log-ratios do not differ statistically (t-test, P=0.10). These ratios (both in images and sections) show that the perikymata intervals in old are larger than in modern teeth (pooled geometric mean ratio=1.28), perikymata intervals in old teeth are 28% larger than in the modern teeth.

Results

In the pictures (P) the modern (M), n=52 teeth had a mean perikymata growth interval (PGI) of 2.51 μm versus the old (O) n=249, ~1500 year old teeth, PGI 3.01 μm P<0.0001. In the sections (S) M n=32

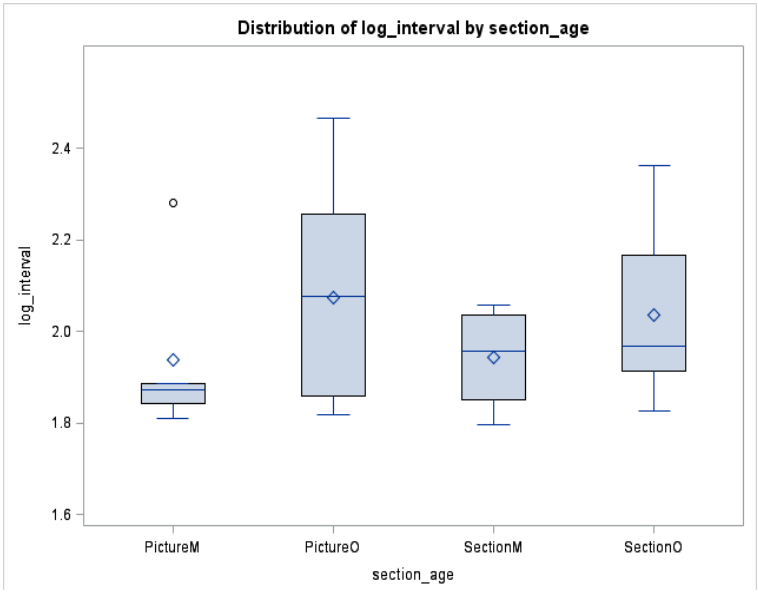

Figure 2: Box plots of perikymata width in images and sections of old (O) and modern (M) teeth.

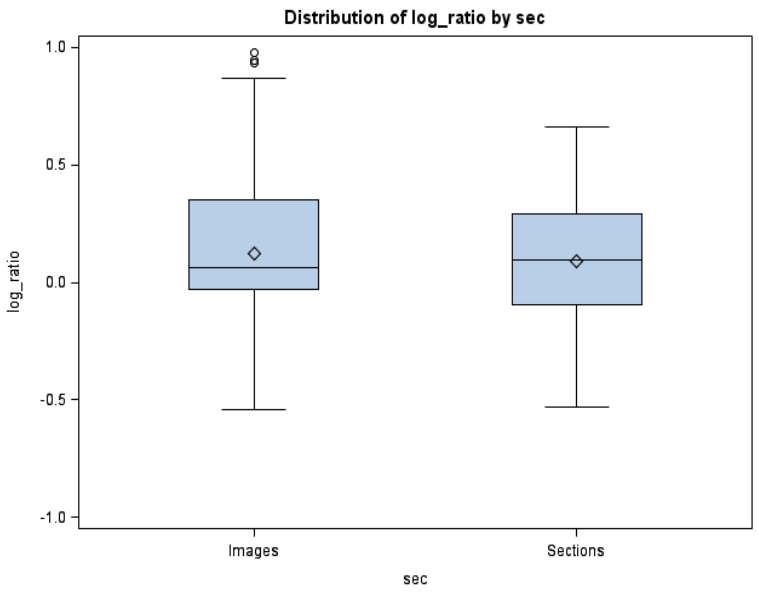

Figure 3: Boxplots of perikymata interval ratios (old/modern) between measurements in sections; Logarithm of ratios symmetrize the skewed distributions of ratio.

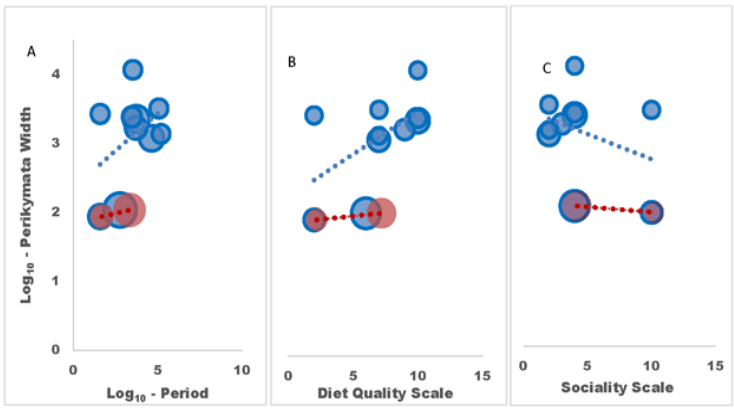

Figure 4: A. Enamel growth perikymata interval (logarithm transformed) vs. period from old times (right) to modern times (left) for images (blue circles) and sections (red circles); size of circles represent sample size (largest circle n=64). Slopes: images (blue), r=0.52, P<0.001; sections (red), r=0.22, P=0.03. B. Enamel growth perikymata interval vs. Diet quality scale (assigned values 1-10 with 10 reflecting worst diet-modern. Slopes: images (blue), r=0.58, P<0.001; sections (red), r=22, P=03. C. Enamel growth perikymata interval vs. Sociality scale (assigned values 1-10 with 10 reflecting most social networks-modern. Slopes: images (blue), r=-0.32, P<0.001; sections (red), r=-0.22, P=0.03.

teeth had a mean PGI of 1.94 μm versus O, n=64 mean PGI 2.04 μm P<0.015. The influence of diet and sociality on the width of perikymata intervals is shown in (Figure 4).

Discussion

The study of ancient specimens is limited by their scarcity, the need for conservation and ethical considerations. But images of such specimens are usually available on the web. Here we take advantage of web based images of teeth and model perikymata interval measures (the striae of Retzius) in the images. We then use sectioned molars and compare the microscopic image measurements, statistically, with those obtained from the web. Anthropologists and evolutionary biologists have for decades been studying perikymata intervals in teeth and have concluded that life style, evolutionary history; dietary and other stresses can reliably be inferred from tooth's growth lines on the surface of teeth (linear enamel hypoplasias LEH) that is perikymata interval measurements (the striae of Retzius in sections) [3].

One accepted view is that closely spaced perikymata intervals (growth lines) indicate a slower rate of growth, while more widely spaced perikymata point to faster growth [5]. We, therefore, conclude that our data support the view that ancient teeth grew faster than teeth of modern humans. Additional factors that may affect the results may have been the absence of artificial light in ancient times which has been shown to have caused wider spaced perikymata intervals and therefore faster growth [6].

In our histological sections, used here as standards for overall result interpretations, wider perikymata intervals were present in ancient teeth (1500 years old) and more closely spaced perikymata spacing (narrower perikymata intervals) was the hallmark of modern teeth, consistent with a slower rate of growth in modern times. These results also support the view that ancient teeth grew faster than teeth of modern humans.

We then turned to elucidating the factors that may have contributed to the faster growth of ancient teeth. We combined measures of dietary habits, perceived stress and sociality [7,8] in the life of ancient humans to infer the effects of these measures on perikymata growth-intervals (Table 1).

Humans and other species compete for survival. In ancient times this competition was aided by proper diet and territoriality that is the available living space. In more modern times territoriality has been affected by "globalization" in the economy aided by increased networking that is the sociality as reflected in our arbitrary scoring system.

Many indicators of physiological and dietary stresses are discernible on the surfaces of teeth; these are impossible to gauge on internet based images. But these defects are ultimately reflected in the measured width of the perikymata intervals, our gold standard, and thus are consistent with our results.

We used the web based images in prehistoric humans such as Neanderthals (Homo neanderthalensis) and other members of the genus homo for this analysis. The results supported our initial hypothesis and correspond to our standard obtained from measurements of perikymata intervals in the histological sections.

Amongst several archaic humans the Denisovans (Homo sapiens ssp. Denisova) are known from only one partial digit of a child and three teeth [9] and these pictures confirmed the wider growth intervals in this homo compared to modern human histological sections.

Thus in ancient teeth the faster growth of teeth resulted from a combination environmental, nutritional and life style influences which have conferred evolutionary advantages on human populations throughout prehistoric and modern times.

We find ancient humans needed faster tooth growth to survive but in modern times highly refined foods and greater connectivity lead to significant slowing of tooth growth appropriate for modern life styles.

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