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A new method of calculating human deciduous enamel formation times

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Introduction

Knowledge of deciduous crown formation times is useful in forensic work and for aging individuals in an archaeological context. Until now, histological techniques for calculating enamel formation times in deciduous teeth have been completely dependent on being able to visualise good daily incremental markings in enamel.

From a sample of approximately 100 longitudinal ground sections of deciduous mandibular teeth, we selected four of each tooth type that exhibited clearly visible daily enamel cross-striations along the prism paths in all regions of the crown between the enamel dentine junction (EDJ) and the enamel surface.

Cumulative daily cross-striation counts were made along these prism paths and recorded at every 100µm of enamel thickness, from the EDJ to the enamel surface in the occlusal, lateral and cervical regions of each tooth type. This procedure was repeated on both lingual and labial / buccal aspects of each ground section. Linear regression equations to predict the time taken to form a given thickness of enamel along a prism path were then generated for each aspect and each region of each tooth type.

We then used these regression equations to calculate deciduous crown formation times in 50 teeth where it was not possible to see daily increments. The sum of individual formation times along a series of time-consecutive prism paths within a tooth equals the total deciduous enamel formation time. The new estimates of deciduous crown formation times presented here corresponded well with previously published estimates. This method of calculating deciduous crown formation times can be used for analysing sections of either archaeological or forensic material where daily increments are often poorly preserved or invisible. The only requirement is that tooth sections preserve a number of accentuated markings in the lateral enamel that define the original orientation of the mineralising front during enamel formation.

Materials and Methods

Ground sections approximately 100µm thick were made in the true buccolingual axial plane of deciduous mandibular teeth. Twenty (four of each tooth type) were then selected on the basis that they exhibited clearly visible daily enamel cross-striations along the prism paths, between the enamel-dentine junction (EDJ) and the enamel surface in all regions.

1) Photomontages were constructed of the lingual and labial / buccal aspects of each section. Each aspect of the crown was divided into occlusal, lateral and cervical regions, Figure 1.

2) Distances of 100µm measured along a single prism path (or axis) were identified in each region of each aspect of each crown (Figure 2). A 50µm zone was included near the surface if the enamel stopped significantly short of a 100µm measurement (1). Cross-striation counts were then made along the prism paths and the sum of all intervals recorded and cumulated at every 100µm, and the final 50µm between the EDJ and the enamel surface. This procedure was repeated in occlusal, lateral and cervical regions of each tooth type and on both lingual and labial / buccal aspects of each ground section.

3) Simple linear regression equations of enamel thickness (µm) along a prism path on the y-axis were plotted against enamel formation time (number of daily cross-striations) on the x-

axis (see Results).

4) Another sample of 50 different deciduous ground sections (ten of each tooth type) was then selected where the neonatal line and additional accentuated striae were visible but where daily incremental markings were not necessarily well preserved. Following the method of Boyde (2), Risnes (3) and Dean (4), prisms were tracked out from the EDJ to an accentuated line which was then followed back to the EDJ at a lower point, the procedure was repeated until the end of enamel formation (Figure 3).

5) Regression equations that combined data from similar regions were then used to calculate the average number of days of formation from the EDJ to the enamel surface together with upper and lower 95% confidences limits.

Results

Figure 4 shows plots for each tooth type together, from which it is clear that the second deciduous molars form enamel at a slightly slower rate than the other deciduous tooth types. Enamel is also thicker and takes longer to form in second deciduous molar cusps.

Conclusions

The estimates of total deciduous crown formation times presented here corresponded well with previously published estimates (5-8).

The regression equations given in Figure 5 can be used to calculate prenatal and postnatal enamel formation times in longitudinal ground sections of deciduous tooth crowns. These data in turn, may be useful for indicating either premature or late birth.

This method of calculating deciduous crown formation times can be used for analysing sections of either archaeological or forensic material where daily increments are poorly preserved or invisible. The only requirement is that tooth sections preserve a number of accentuated markings in the lateral enamel that are visible in transmitted polarized light. Future work will reveal if there is worldwide variation or not in both rates of deciduous enamel formation and / or deciduous crown formation times. Until such time it would be prudent to assume that this may well be the case.

Acknowledgements

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		Mean (days)	% Crown completion	Lower 95% CL	Upper 95% CL	Range (days)	Weeks	Months
Central incisors	Crown formation time before birth	144	60.0	137	152	15	20.6	4.74
	Crown formation time after birth	96	40.0	89	103	15	13.7	3.16
	Total crown formation time	240	100	226	255	30	34.4	7.90
Lateral incisors	Crown formation time before birth	136	54.8	131	142	11	19.5	4.48
	Crown formation time after birth	113	45.2	107	119	12	16.1	3.70
	Total crown formation time	249	100	238	260	22	35.6	8.18
Canines	Crown formation time before birth	128	29.8	121	135	14	18.4	4.22
	Crown formation time after birth	302	70.1	280	322	42	43.1	9.91
	Total crown formation time	430	100	401	458	56	61.4	14.13
First molars	Crown formation time before birth	140	43.0	135	146	11	20.0	4.61
	Crown formation time after birth	186	57.0	175	197	21	26.5	6.10
	Total crown formation time	326	100	310	342	33	46.6	10.71
Second molars	Crown formation time before birth	118	23.2	113	122	8	16.8	3.86
	Crown formation time after birth	389	76.8	373	403	30	55.5	12.77
	Total crown formation time	506	100	487	524	38	72.3	16.64

Table 1. Total crown formation times were calculated for each deciduous tooth type on the longest forming buccal aspect, using the sum of the times calculated for each of the prism paths measured from the EDJ. (1 week = 7days; 1 month = 30.44 days).

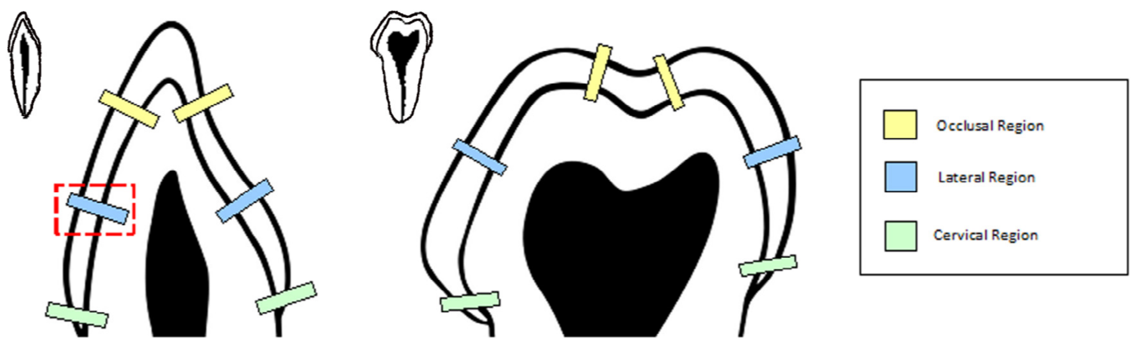

Figure 1. Diagrams illustrating how each longitudinal tooth section was divided into cervical, lateral and occlusal regions in both anterior and posterior teeth.

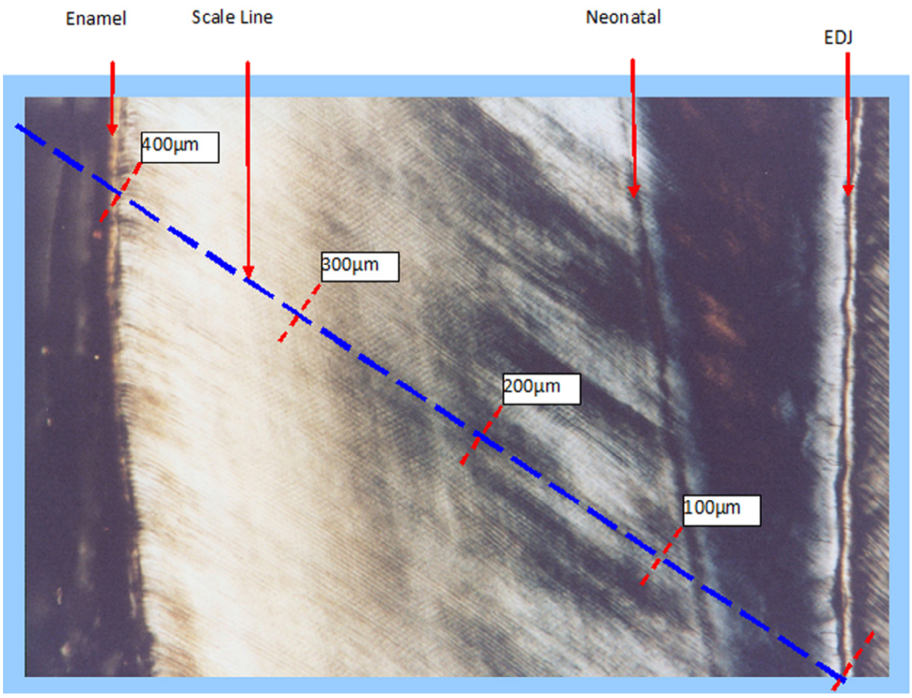

Figure 2. The lateral region of the labial aspect of a deciduous canine. The enamel surface, scale line along the prism axis (broken blue line), neonatal line and enamel dentine junction are indicated. The distance along the prism axis from the EDJ to the enamel surface was measured to create 100µm intervals (± a final 50µm interval) along the prism path (short broken red lines crossing the long broken blue line). Within each of these intervals a cross-striation count was made and cumulated from the EDJ to the enamel surface.

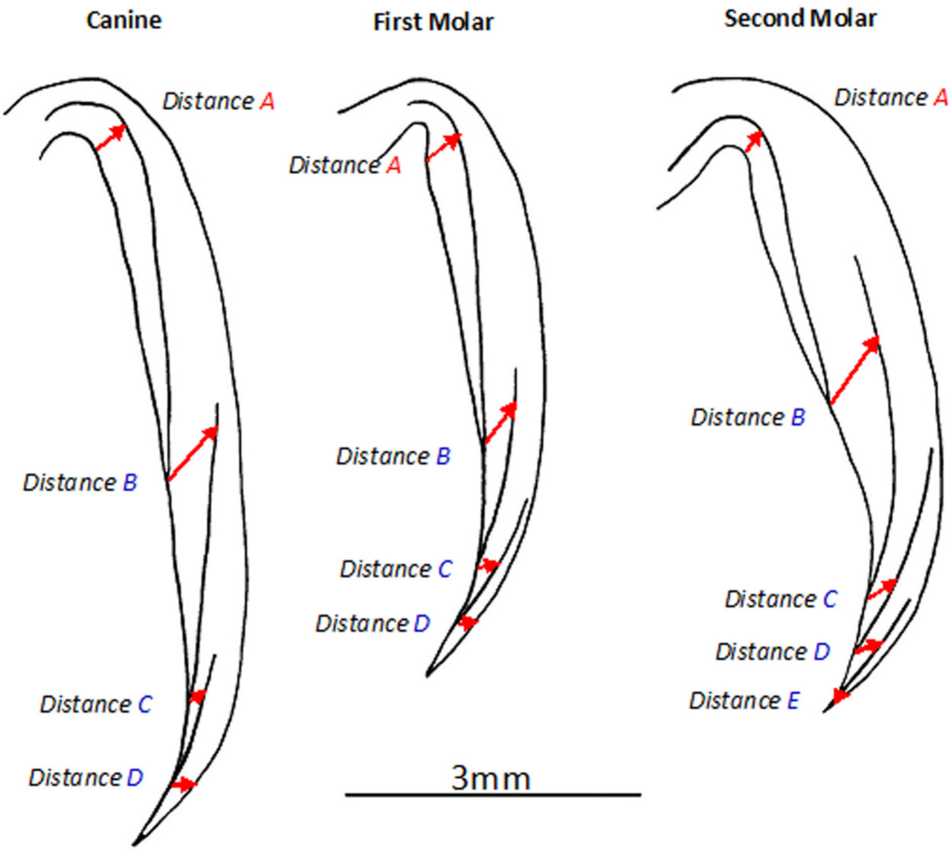

Figure 3. Diagrams made using a drawing tube to illustrate how crown formation times, before and after birth, were measured within the buccal aspect of each of the ten photomontages of each tooth type. In all teeth the first line represents the neonatal line and 'Distance A' the thickness of enamel formed prenatally Measurements were made from the EDJ along a prism path (red arrows) first to the neonatal line. This was then traced back to the EDJ at a lower point in the crown. This process was then repeated to the next formed accentuated stria until the most cervical point of the enamel was reached. Each measurement (red arrow) on each photomontage represents an example of 'x' in the regression formulae used to predict a formation time from the EDJ. The sum of these times was taken as the estimate of total crown formation time.

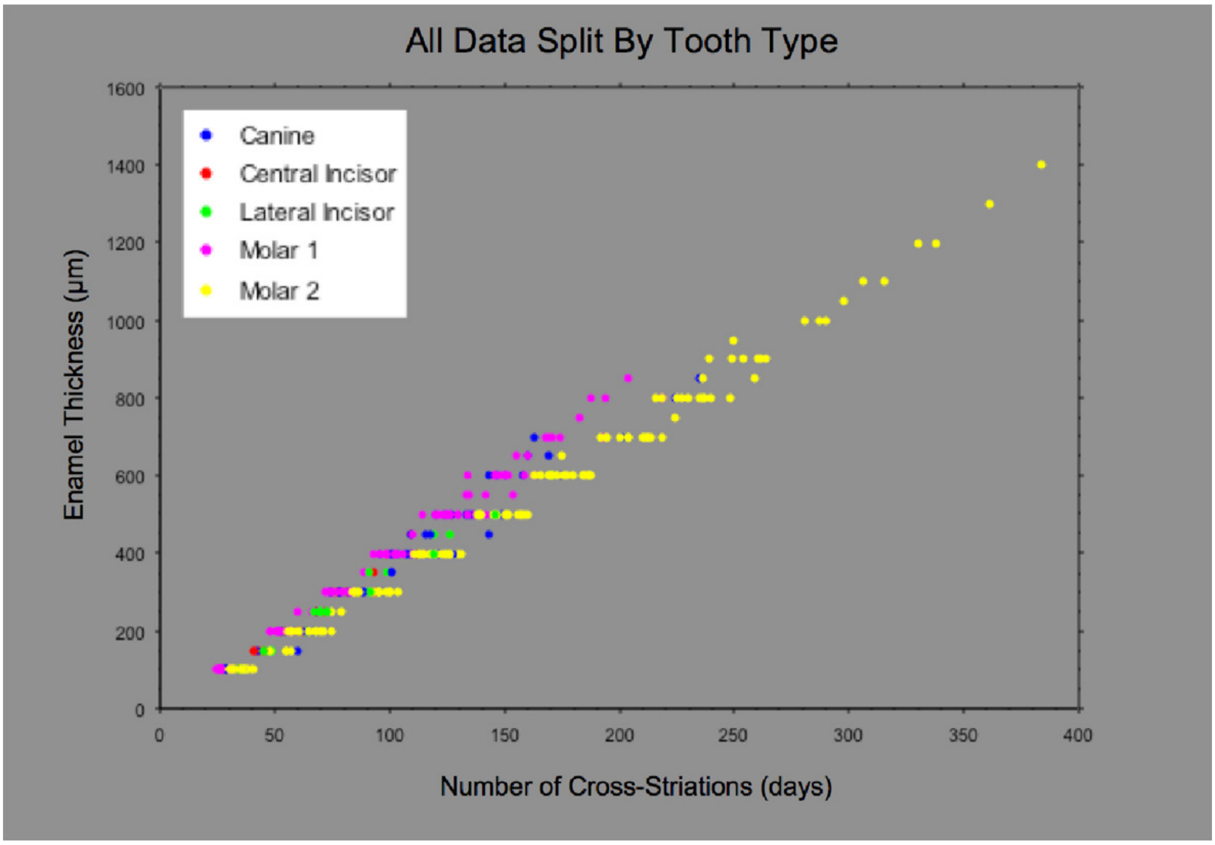

Figure 4. Bivariate scattergram showing the data obtained for all aspects and all regions of the crowns. The data are split by tooth type and show that rates of enamel formation are slower in second molars and that some prism paths in second molars (e.g. occlusal paths) have longer formation times.

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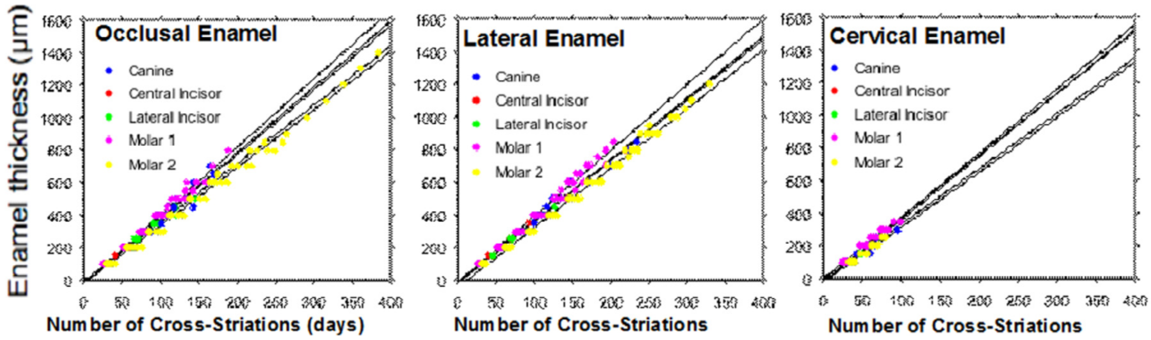

Occlusal Enamel	Lateral Enamel	Cervical Enamel
Y = - 23.621 + 3.966 * X	Y= - 10.097 + 3.743 * X	Y = - 8.636 + 3.401 * X
R^2 = .962 (Canine)	R^2 = .981 (Canine)	R^2 = .897 (Canine)
Y = - 24.01 + 4.033 * X	Y = - 14.069 + 3.709 * X	Y = - 23.769 + 3.953 * X
R^2 = .978 (Central Incisor)	R^2 = .979 (Central Incisor)	R^2 = .98 (Central Incisor)
Y = - 4.595 + 3.608 * X	Y= - 23.337 + 3.792 * X	Y = - 28.881 + 3.881 * X
R^2 = .986 (Lateral Incisor)	R^2 = .989 (Lateral Incisor)	R^2 = .97 (Lateral Incisor)
Y = - 22.48 + 4.213 * X	Y= - 16.483 + 4.036 * X	Y = - 1.988 + 3.792 * X
R^2 = .987 (Molar 1)	R^2 = .986 (Molar 1)	R^2 = .972 (Molar 1)
Y = - 20.705 + 3.571 * X	Y= - 43.436 + 3.651 * X	Y = - 22.913 + 3.39 * X
R^2 = .991 (Molar 2)	R^2 = .993 (Molar 2)	R^2 = .953 (Molar 2)

Figure 5. These plots show data for different regions of the crown split by tooth type. No differences exist between regions within a tooth type but deciduous second molars (yellow symbols) form enamel at a slightly slower rate than the other deciduous tooth types. The regression formulae and coefficient of determination, R2, for each region of each tooth type appear below the graphs.