Serial Data on Primary Canine Root Resorption and Gingival Emergence of Permanent Successors

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This investigation pertains to the course of root resorption of maxillary and mandibular primary canine teeth studied from initial root resorption of each tooth to gingival emergence of its successor. The study parallels a previous report on the primary incisor teeth.[4] Data are derived from intraoral roentgenograms and records obtained through longitudinal study of 116 North American white children.

OBJECTIVES

Data on resorption of the roots of the primary canine teeth are analyzed:

1. To determine, for each sex, the median age and variability in age for three stages of root resorption designated (a) initial, (b) one-half, and (c) three-fourths.

2. To discover individual differences in the interval of time from each of these root resorption stages to gingival emergence of permanent canine teeth.

3. To classify and tabulate types of root resorption at initial and advanced stages.

4. To examine relationships between resorption age, gingival emergence age, and length of resorption time for canine teeth.

5. To compare the results of this study with (a) findings on the incisor teeth for the same sampling of children and (b) results of other investigations on the canine teeth.

SUBJECTS

The subjects were fifty-six boys and sixty girls living in or near Iowa City, Iowa, voluntary participants in a long-term research program conducted at the University of Iowa.* Enrollment was based on willingness to cooperate and likelihood of permanency of residence in the area.

The population sampled may be characterized further as healthy white children predominantly of northwest European ancestry and above average in socioeconomic status.

MATERIALS AND METHODS

Data were derived from intraoral roentgenograms obtained semiannually from ages four through twelve years, and at annual intervals thereafter.

For each child, age estimates at three stages of root resorption (initial, one-half and three-fourths) were made on the left mandibular and maxillary primary canine teeth. In some instances when satisfactory data on the left tooth could not be obtained, data on its antimere were used.

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* The Facial Growth Study. Collection of materials was under the joint supervision of Howard V. Meredith (1946-60) with L. Bodine Higley (1946-54) and with Ernest H. Hixon (1954-60).

Serial data from initial resorption of primary canine roots to emergence of permanent canine teeth were complete on 217 of the 232 teeth (two canine teeth on 116 subjects). Fifteen teeth were omitted because for both the left canine and its antimere (a) a relevant film was missing or unclear, (b) successor emergence age was not available, or (c) a tooth was injured or removed.

Age estimates for the three resorption stages were made by two investigators working independently. When these age values agreed within 0.2 years, the average of the two was used. With greater discrepancy, two additional independent judgments were made and either the mean of the four utilized or, when one value represented an obvious error, the mean of the other three.

Approximately 77 per cent of the initial paired independent estimates agreed within the established limits. By category these included 62 per cent of the age values for initial resorption stage, and 85 per cent of the age values for one-half and three-fourths resorption stages. Reliability for age estimates at the three canine resorption stages is lower than reliability of estimates made for comparable stages on central and lateral incisor teeth of the same subjects.[4] It is probable that the location of the canine teeth in the dental arch contributes substantially to these differences in reliability.

"Initial" stage of root resorption is defined as the earliest radiographic evidence of resorption regardless of its location. Resorption stage "one-half" refers to the stage when only one-half of the root mass remains, while resorption stage "three-fourths" means that three-fourths of the total root mass has been resorbed and one-fourth of the root remains.

The type of root resorption was classified independently by the two investigators as lateral, apical, or apical-lateral at the initial stage; and horizontal or diagonal at advanced stages. Instances of disagreement were resolved by repeating independent judgments.

Age of gingival emergence for each of the permanent canine teeth studied had been determined prior to this investigation.[3,7]

In a previous investigation,[4] findings on incisor teeth were derived using the same materials and methods. Selected results will be cited throughout the present study for purposes of comparison and additional analyses.

Age at Different Stages of Primary Canine Root Resorption

For each sex, Table I lists the 10th, 50th, and 90th percentiles for (a) age at three stages of primary canine root resorption in each dental arch and (b) age at gingival emergence of their respective permanent successors. It may be noted that:

1. For each of the three stages of root resorption (initial, one-half and three-fourths) the median ages are earliest for the mandibular canine in girls and latest for maxillary canine in boys.

2. The median ages of initial root resorption on boys are 8.5 years for the mandibular canine, and 8.8 years for the maxillary canine. The median values for girls are close to one year earlier.

3. Typically, the roots of the mandibular canines in boys and maxillary canines for girls are one-half resorbed near age 9.5 years. One-half resorption occurs about 12 months earlier for mandibular canines in girls and 6 months later for maxillary canines for boys.

4. In the lower arch 50 per cent of the girls show three-fourths root resorption at age 9.1 years, with successor emergence at 9.7 years. The corresponding values for boys are 0.8 years later.

TABLE I

Age (in years) for Three Stages of Primary Canine Root Resorption and for Gingival Emergence of Permanent Successors

Tooth Stage	Percentiles					
	10	50	90	10	50	90
	Males			Females		
Mandibular Canine (54 males, 59 females)						
Root Resorption:						
Initial	6.4	8.5	9.9	6.0	7.4	9.1
One-half	7.9	9.6	10.6	7.3	8.7	10.2
Three-fourths	8.3	9.9	10.9	7.7	9.1	10.5
Successor Emergence	9.3	10.5	11.6	8.5	9.7	11.2
Maxillary Canine (48 males, 56 females)						
Root Resorption:						
Initial	7.0	8.8	10.3	6.6	7.9	9.4
One-half	8.6	10.1	11.1	8.2	9.5	11.4
Three-fourths	9.0	10.4	11.6	8.6	9.8	11.9
Successor Emergence	10.0	11.2	12.6	9.4	10.8	12.7

In the upper arch analagous values are 9.8 and 10.8 years for girls, 10.4 and 11.2 years for boys.

5. At initial resorption age, variability for the central 80 per cent ranges from 34 to 42 months. For both canine teeth the variability is about 6 months less for girls than for boys.

6. At stages of one-half and three-fourths resorption, and at successor emergence, there is a maximum difference in age among the central 80 per cent of about two and one-half years for boys and about three years for girls.

Among boys, median age of initial root resorption for canine teeth is three years later than for the central incisor teeth; for girls, corresponding differences are two years in the upper arch and two and one-half years in the lower arch.

Individual Variation in Time Interval for Root Resorption

From the serial data individual values for time between age at different stages of root resorption and age at gingival emergence of permanent successor were determined. In Table II,

TABLE II

Time (in months) from Three Stages of Primary Canine Root Resorption to Gingival Emergence of Permanent Successors

Interval	Canine Tooth	Percentiles*				
		10	25	50	75	90
Initial Root Resorption to Successor Emergence	Mandibular	11	15	26	36	42
	Maxillary	18	23	32	43	50
One-half Root Resorption to Successor Emergence	Mandibular	7	8	10	14	20
	Maxillary	9	11	14	18	24
Three-fourths Root Resorption to Successor Emergence	Mandibular	3	5	7	9	14
	Maxillary	5	7	9	13	17

* For each tooth, percentiles are based on approximately 50 boys and 55 girls.

five percentile points whose values are based on the distribution of three intervals for each of the canine teeth are shown for the sexes combined.*

It is noted:

1. The full course of root resorption and shedding for maxillary and mandibular canine teeth occurs in about two to two and one-half years for 50 per cent of this group of children. Initial resorption to successor emergence occurs in four years or less for 90 per cent of the children.

2. From the time when one-half of the root was resorbed, 50 per cent of the children showed emergence of the permanent successor within approximately one year, 90 per cent within two years.

3. The interval from three-fourths resorption to successor emergence is less than 9 months for 50 per cent of these children, and less than 17 months for 90 per cent.

4. The time intervals to successor gingival emergence from initial, one-half, and three-fourths primary root resorption are shorter for the lower canine than for the upper.

5. The six distributions presented are all positively skewed. For example, the spread from one-half root resorption to successor emergence for the mandibular canine is 3 months between the 10th and 50th percentile and 10 months from the 50th to the 90th percentile.

Comparison of previous findings on incisor teeth with canine data shows the full course of root resorption from initiation to successor emergence to be longest for the canines (medians, 26-32 months), intermediate for maxillary incisors (15-20 months) and shortest for mandibular incisors (7-13 months).

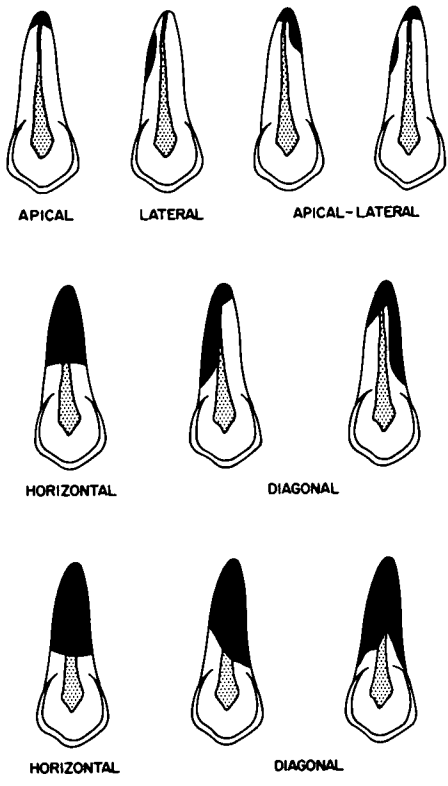

Fig. 1 Varieties of primary canine root resorption at three stages: initial (top row), one-half (middle row) and three-fourths (bottom row).

Variation in Pattern of Resorption

Throughout the course of root resorption, several resorption types were classified as shown in Figure 1. At the initial stage three types are differentiated according to the area first showing resorption: *apical* (resorption noted at the apex of the root only), *lateral* (resorption only on a lateral aspect of the root), and *apical-lateral* (initial resorption laterally and at the apex). For advanced stages, after at least one-fourth of the root was resorbed, two types were distinguished. *Horizontal* designates resorption that appears rela-

* The Whitney-Mann U test was used to test the hypothesis that the distribution of intervals was the same for the two sexes. This null hypothesis could not be rejected for any of the six distributions at the 1 per cent level of confidence.

TABLE III
Classification of Root Resorption

A. *Initial Stage*

Canine Tooth	Number Observed	Type of Resorption					
		Apical		*Lateral*		*Apical-Lateral*	
		N	Per cent	N	Per cent	N	Per cent
Mandibular	99	45	45.4	39	39.4	15	15.2
Maxillary	87	30	34.5	32	36.8	25	28.7

B. *One-half Stage*

Canine Tooth		Type of Resorption			
		Horizontal		*Diagonal*	
		N	Per cent	N	Per cent
Mandibular	103	52	50.5	51	49.5
Maxillary	97	21	21.6	76	78.4

C. *Course from Initial to One-half Stage*

Initial Resorption		Later Resorption			
		Horizontal		*Diagonal*	
		N	Per cent	N	Per cent
Apical	72	49	68.1	23	31.9
Lateral	68	8	11.8	60	88.2
Apical-Lateral	37	8	21.6	29	78.4

tively symmetric, that is, roughly paralleling a line perpendicular to the long axis of the primary canine tooth. Resorption classed as *diagonal* is asymmetric and may involve resorption of either or both sides of the root.

Assembled in Table III are data on types at early and later resorption stages. The upper portion of the table shows the frequency of type of initial resorption for 186 canine teeth based upon films showing resorption of less than one-fourth of the root mass. This subgroup includes approximately 88 per cent of lower canine and 84 per cent of upper canine teeth of the total sample. Findings from this section of the table are:

1. For the mandibular canine tooth, initial resorption was rated as apical in 45 per cent of the teeth, lateral in about 40 per cent, and apical-lateral in the remaining 15 per cent.

2. For the maxillary canine tooth, initial resorption was classified as lateral, apical or apical-lateral with nearly equal frequency.

3. For the 186 canine teeth taken together, the apical and lateral types of initial resorption were observed with about equal frequency (40 per cent for each tooth). The remaining 20 per cent were rated apical-lateral.

On the incisor teeth, lateral initial resorption was the most frequent type for both the lateral incisors and the upper central incisor, while apical resorption was most typical for the lower central incisor.

The time interval from initial resorption to successor emergence did not differ significantly with respect to the location of initial resorption on the incisor teeth. Among the canine teeth, for the group with initial lateral involvement, resorption began at an earlier age and the time interval to stage one-half was longer. Initial lateral resorption appeared to result primarily from "ectopic eruption" of the permanent lateral incisor teeth.[1,6,9]

For the 71 canine teeth showing initial lateral resorption, additional estimates were made for age at the beginning of apical resorption. At the apex, resorption was not observed in some instances until 2.5 years later. The median difference between the initial appearance of resorption and resorption at the apex was just over one year for 39 mandibular canines and 10 months for 32 maxillary canines.

The median value for total time from initial root resorption to successor emergence was 23 months for mandibular and 28 months for maxillary canine teeth when initial resorption was taken as the earliest evidence of *apical* involvement in each case. These medians are 3 to 4 months less than the median values reported in Table II when the earliest evidence of root resorption, regardless of location, is used to determine initial root resorption (26 and 32 months respectively).

Section B of Table III summarizes judgments on type of resorption viewed on 200 films of canine teeth near one-half root resorption. Referring to the table, it will be seen:

1. In the mandibular arch, root resorption for one-half the teeth was rated as horizontal, and diagonal for the other 50 per cent.

2. For the maxillary canine teeth, root resorption for nearly four out of five was rated as diagonal at this stage.

3. Overall, at stage one-half, diagonal resorption was noted in 65 per cent of canine teeth, horizontal in 35 per cent.

Combining these results with those found for primary incisor roots, it may be noted that in the maxillary arch when one-half the root mass has been resorbed, the radiographic pictures typically revealed an irregular (diagonal) pattern of resorption for the lateral incisor (89 per cent of the time), canine (78 per cent) and central incisor (66 per cent). In the mandibular arch a more regular pattern (horizontal) was more often seen at later stages for the central incisor (78 per cent), lateral incisor (55 per cent), and canine (51 per cent).

The final section of Table III presents the subsequent course of resorption for the three initial types. For 177 of the 186 teeth in section A, there was also a later film near stage one-half showing resorption categorized as horizontal or diagonal. From section C, note that 70 per cent of the time, apical initial resorption was followed by the horizontal type, while lateral initial resorption progressed to a diagonal type in nearly 90 per cent of teeth, and from apical-lateral to a diagonal type for approximately 80 per cent. These percentages are similar to those found for the incisor teeth.

Associations for the Incisor and Canine Teeth Between Resorption Age, Gingival Emergence Age, and Duration of Resorption Time

Assembled in Table IV are correlation coefficients (r's) for various relationships for age at given resorption stages and intervals from selected resorption stages to successor emergence.

Section A presents correlation coefficients between age at each of three canine root resorption stages and interval from this designated stage to successor emergence. This portion of the table shows:

1. The obtained negative coefficients for age at designated resorption stage and interval to successor emergence vary in size from .12 to .61. For pairings yielding r's above .25, the hypothesis that the obtained correlation could have occurred by chance (assuming no association for the population) may be rejected at the 1 per cent level of confidence.

TABLE IV
Correlation Coefficients*

A. AGE at given resorption stage with INTERVAL from this stage to gingival emergence.

RESORPTION STAGE	CANINE TOOTH *Mandibular*	*Maxillary*
Initial	–.61	–.43
One-half	–.45	–.16
Three-fourths	–.40	–.12

B. AGE (initial resorption) between incisor and canine teeth.

TOOTH	*Mandibular* Lateral incisor	*Mandibular* Canine	*Maxillary* Central incisor	*Maxillary* Lateral incisor
Mandibular				
Central incisor	.83	.62	.63	
Lateral incisor		.70		.71
Maxillary				
Lateral incisor			.64	
Canine		.60	.54	.66

C. INTERVAL (initial resorption to successor emergence) between incisor and canine teeth.

	Mandibular Lateral incisor	*Mandibular* Canine		*Maxillary* Lateral incisor	*Maxillary* Canine
Mandibular			*Maxillary*		
Central incisor	.29	.10	Central incisor	.46	.50
Lateral incisor		.39	Lateral incisor		.37
Canine					.32

* Correlations (r's) were computed separately for each sex and combined. N's are approximately 50 boys and 50 girls.

2. Association between age at initial resorption stage and subsequent interval to successor emergence was moderate for the mandibular canine, indicating that early initial resorption for this tooth is somewhat associated with the longer intervals to successor emergence and later initial resorption with shorter intervals. The same variables for the maxillary canine tooth show a low negative relationship ($r = -.43$).

3. The variables of age at one-half root resorption and interval to successor emergence show a low negative relationship in the case of the mandibular canine tooth and no relationship for maxillary canine teeth. Similar values were obtained for age at three-fourths resorption.

Taken collectively, these findings on canine teeth closely parallel results obtained for central and lateral incisor teeth on the same group of children.

In section B of Table IV, correlation statistics are displayed for age at initial resorption among incisor and canine teeth located within the same dental arch and complementary incisor and canine teeth located in opposing dental arches. Correlation coefficients lie between $r = .54$ and $r = .83$. The highest relationship for age at initial root resorption is found for the mandibular central with the mandibular lateral

incisor, the lowest for the maxillary central incisor with the maxillary canine. Summarizing, the statistics presented in this portion of Table IV support the generalization that early resorption of a given primary incisor or canine root is likely to be associated with younger than average age for initial resorption of the incisor and canine teeth in the same dental arch and with its complementary tooth in the other dental arch. Conversely, late initiation for one is likely associated with older ages for canine and incisors in the same arch, and its complementary tooth in the other. However, the relationships found between the incisor and canine age values were not sufficiently high to reduce errors of prediction by as much as 30 per cent.

The final section of Table IV presents *r*'s for interval from initial resorption to successor emergence for combinations of incisor and canine teeth in the same dental arch and for complementary canine teeth. These correlation coefficients are low positive, ranging between .10 and .50. Thus there is slight indication that a relatively long interval from initial resorption to successor emergence for one primary incisor or canine tooth is likely to be associated with a longer than average time interval for other incisor and canine teeth in the same subject.

It was also found that relationships between upper and lower canine teeth were negligible for interval from (a) one-half root resorption to successor emergence and (b) three-fourths to emergence. The *r*'s were .23 and .29, respectively.

Concerning order of beginning canine root resorption: lower canine root resorption was earlier for 57 per cent of the boys and 77 per cent of the girls. For the central 80 per cent of the subjects, timing variation ranged from the upper canine root showing resorption 10 months earlier to 24 months later than the root of the lower tooth.

Comparisons with Two Other Studies on the Mandibular Canine

Literature examination was conducted to locate research reports on primary canine root resorption. No studies on maxillary canine root resorption were found; two studies included data on a portion of the resorption stages for the mandibular tooth.

Fanning[2] listed percentile values at initial, one-fourth, and one-third stages of root resorption on the lower canine for each sex. Data were obtained from serial intraoral films made on lower middle class Boston children primarily of northwest European ancestry participating in the Harvard Growth Study (from 1934 on).

Moorrees, Fanning and Hunt[5] presented charts of mean age and variation in age for one-fourth, one-half, and three-fourths stages of resorption. Subjects were middle class Ohio children of northwest European descent, participants in the Fels Study begun about 1930. The data source was serial oblique or lateral jaw films.

These two studies do not differ markedly from the present study with respect to type of population sampled or secular period.

Data from the three studies are assembled in Table V. Central tendency values for age at resorption stages on the three groups of children are recorded. Note that:

1. There is over a two year spread for ages at initial resorption. The present study has listed 8.5 years (boys) and 7.4 years; Fanning, 6.2 and 5.2 years; Moorrees et al., at ages earlier than 6.1 and 4.9 years.

2. Wide differences are found between age values at stage one-fourth.

TABLE V

Data (age in years) on Mandibular Canine Teeth from Three Longitudinal Studies of Healthy, White American-born Children

STAGE	INVESTIGATION					
	Fanning*		Moorrees, Fanning and Hunt**		O'Meara and Knott*	
Primary Root Resorption	Boys	Girls	Boys	Girls	Boys	Girls
Initial	6.2	5.2			8.5	7.4
One-fourth	7.6	7.4	6.1	4.9		
One third	8.9	8.7				
One-half			8.4	7.3	9.6	8.7
Three-fourths			9.8	8.7	9.9	9.1
Exfoliation			10.6	9.5		
Successor Emergence					10.5	9.7

* Median ages.

** Mean ages read from charts.

Fanning reported 7.6 years for boys and 7.4 years for girls, while from Moorrees et al. ages are 6.1 and 4.9 years, respectively.*

3. There is a difference of over one year for age at one-half resorption in the two studies reporting this value. Again, the age for Iowa children was found to be later. Moorrees et al. found the mandibular canine roots to be, on the average, one-half resorbed at the age when only 50 per cent of Iowa children showed initial resorption on any portion of that tooth.

4. The time from one-half to three-fourths resorption was 4 to 5 months in the present study and about 17 months from Moorrees et al. so that at three-fourths resorption the two studies yield similar age values.

5. Both the present report and that of Moorrees et al. show roughly a one year age differential between the sexes for the same stages. While Fanning reported the same age differential at initial resorption, her values at one-fourth and one-third differ by about only 3 months for the two sexes.

No single factor affords a definitive explanation for these wide age differences; the differences may be discussed with reference to variations in techniques employed and classification of stages.

The studies by Moorrees et al. and by Fanning employed the same techniques to determine age values. Smoothed, weighted estimates for each stage were based on percentages of children at each age that had attained a stage of resorption. By contrast, in the present study age estimates were made for each child individually and tabulated to obtain median age and percentile values.

Concerning classification of stages: both Fanning and Moorrees et al. defined initial resorption as the stage where the root shows blunting or rounding at the apex and additional stages were assessed by reference to a series of drawings of symmetric reduction in root length. These drawings are comparable to the initial apical resorption followed by subsequent horizontal types illustrated in Figure 1.

In the present report it was found

* Paired comparisons between the two studies showed little difference in age values for root formation and apical closure of these mandibular primary canines.

that 60 per cent of the 113 mandibular canine roots did not follow a regular pattern of resorption beginning at the apex and proceeding symmetrically in reduction of root length. Only 25 per cent clearly conformed to the pattern outlined by the other two studies, while resorption proceeded too rapidly to classify with assurance the remaining 15 per cent. The asymmetric pattern of root resorption shown by lateral and diagonal types seen on the film may also be noted clinically on extracted primary canine teeth.[8] It is not clear how these asymmetric types would be assessed according to charts depicted in the two other studies.

Summary

The course of primary canine root resorption from initiation to gingival emergence of the successor was investigated. Data were obtained from intraoral roentgenograms and records on 116 Iowa children of northwest European ancestry and above average socioeconomic status enrolled in a longitudinal research program. Estimates of age at three stages of root resorption (a) initial, (b) one-half and (c) three-fourths, were made for the left primary canine in each dental arch by two raters working independently.

Findings relative to specific aims listed in the study are:

1. The median ages at initial root resorption are 8.5 and 8.8 years for the mandibular and maxillary canine in boys; 7.4 and 7.9 years for girls.

2. The full course of root resorption for upper canine teeth is completed in about two years for 50 per cent of the boys and girls; for lower canine, in about two and one-half years. Ninety per cent of the children complete this process in under four years.

3. From one-half root resorption to successor emergence, median time intervals are 10 months for the maxillary canine, 14 months for the mandibular canine. For the interval from three-fourths resorption to successor emergence, the values are 7 months and 9 months respectively.

4. Initial canine root resorption was rated as lateral or apical with about equal frequency. The course of resorption to one-half stage is seen to proceed from apical to horizontal or from lateral to diagonal over 70 per cent of the time.

5. Coefficients of correlation for age at designated canine resorption stage with interval to successor emergence vary in size from $r = -.12$ to $-.61$. These findings on canine teeth closely parallel results obtained for incisor teeth on the same children.

6. The variables of age at initial resorption for complementary canine and for incisor and canine teeth located in the same dental arch show moderate positive relationships (r's from .54 to .70).

7. Coefficients of correlation for interval from initial resorption to successor emergence between incisor and canine teeth in the same dental arch and for complementary canine teeth are low positive, ranging between .10 and .50.

8. Generally, initial mandibular canine root resorption was earlier than initial maxillary root resorption. Timing variation ranged from upper canine root resorption 10 months earlier to 24 months later than the lower canine root.

9. Comparison of findings from the present study with results of two other investigations on mandibular canine root resorption show differences among the three studies. These differences are particularly striking with respect to (a) age at initial root resorption and (b) types of resorption, initially and at advanced stages.

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