Economic Impact on Tooth Emergence

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ABSTRACT As shown in nearly 10,000 Negro and White boys and girls between 4.5 and 16.5 years of age, poverty-level children (with an income-to-needs ratio of 1.0) tend to be delayed in permanent tooth emergence as compared with those approximating median per-capita income. For boys, a per-capita income difference of $2200 was associated with a 0.15 standard deviation difference in emergence timing of 28 permanent teeth.

The effect of socio-economic differences on the emergence timing of the permanent teeth constitutes a fundamental and still-unresolved problem in human dental development. It is relevant, moreover, to population comparisons (where economic differences are so often considerable), and in the analysis of human skeletal remains, where current tooth emergence standards may not be fully applicable. Quantitative information on the economic effect is scant, however, since few studies of tooth emergence have been specifically designed to resolve the fundamental question (cf. Fess, '65; Garn and Russell, '71). The present investigation, therefore, provides new tooth emergence information on a very sizable sample of subjects (N = 9656), separately for youngsters of European and largely-African derivation, and in conjunction with individual data on family income and family composition.

In this tooth emergence study we have made use of precoded presence-absence dental data on 5788 White children (2967 boys and 2821 girls) and 3868 Black or American Negro children and adolescents (1847 boys and 2021 girls). The prime dental data were collected in the course of the ten-State Nutrition Survey of 1968–1970, and represent the eight states where exact birthdate information was reported and recorded (cf. Garn, Nagy and Sandusky, '72; Garn, Sandusky, Nagy and McCann, '72a; Garn, Wertheimer, Sandusky and McCann, '72b; Garn, Sandusky, Nagy and Trowbridge, '73a; Garn, Sandusky, Rosen and Trowbridge, '73b). These states include Massachusetts, New York (including New York City), Michigan, Kentucky, West Virginia, South Carolina, California and Washington. The census designations "White" and "Black" were used for subject identification. As ascertained from the final corrected computer listings, the actual age range encompassed was 4.50 through 16.49 years, as computed from birthdate and date of examination.

For each individual in the survey, family income, family size and age of individuals in the family were together calculated to provide an index of income relative to needs, so calculated that an index of 1.0 represents the poverty level (Orshansky, '65, '68; Ten-State Nutrition Survey, '72). As described in the published report on the Ten-State Survey, "Ratios of less than 1.0 can . . . be described as 'below poverty'; ratios greater than 1.0, as 'above poverty,' A family with a P.I.R. of 1.0 is living at the poverty line." For the present study, two income-needs groupings were selected for comparison, one grouping with income-needs ratios up to 1.49 (and straddling the poverty line of 1.0) and a second income-needs grouping ranging from 2.25 upward (and approximating the median income level for 1968).

We have separately calculated the per-capita incomes for the two groupings used. The median per-capita income for the lower or poverty-level grouping approximated $720 per capita, while the higher income grouping had a median per-capita income of $2920. These median values necessarily differ slightly from age to age and state to state, even though the cutoff values were consistent as given above. The per-capita income difference between the lower and higher income groupings was $2200 for Whites and somewhat less for Blacks.

Recoding the presence-absence data for 28 individual teeth, I1 through M2, so as to count extracted or replaced permanent teeth as "present," tooth emergence information was computer calculated, and initially analyzed state by state to detect and delete possible irregularities of coding or punching. Then the data for all eight states were combined, and analyzed by sex, by race, and by tooth, for each of the two economic groupings, using the publication of Klein, Palmer and Kramer ('37) as an inspectional guide, in data editing throughout.

For the purposes of this study the measure of central tendency calculated was *M*, corresponding to the mean in a Gaussian distribution, as described previously by us (Garn et al., '72a,b). Differences in emergence timing between the two income groupings were then calculated as *d* (difference in years) thus minimizing any bias resulting from choice of a particular algorithm. The direction of the differences (*d*) was tested by a simple sign test, against chance expectancy, to determine whether the higher income grouping was earlier (i.e., advanced) in tooth emergence for each of the sex-race comparisons.

Further, the magnitude of the differences in tooth emergence (*d*) was expressed as Z-scores or standard deviation units, using values of σ, calculated from the total sample, as described in Abramowitz and Stegun ('64). Differences in Z-scores were based upon values of σ appropriate for sex, race and tooth, as set forth in table 1.

Analyzing the income-groupings, then, for possible differences in tooth emergence timing, as reflected by differing values of M, permanent tooth emergence (I1-M2) tends to be systematically delayed in the boys of lower income-needs ratios or lower per-capita incomes. This economic delay in tooth emergence is demonstrated first for White boys where 10 out of 14 combined-side tooth pairings are delayed or later in those in the lower or "poverty level" grouping. It is again demonstrated, separately, for Black or American Negro boys, where 11 out of 14 teeth are delayed

TABLE 1

Variability in permanent tooth emergence timing

Tooth	White children				Black children			
	Boys		Girls		Boys		Girls	
	N [1]	S.D.	N [1]	S.D.	N [1]	S.D.	N [1]	S.D.
				Maxilla				
I1	4434	0.77	3932	0.75	3284	0.82	3104	0.84
I2	4354	1.01	4007	0.91	3598	0.99	2763	1.14
C	6166	1.39	5024	1.40	3949	1.63	2884	1.59
P1	4938	1.41	3775	1.38	3897	1.54	3409	1.46
P2	5358	1.48	4818	1.56	4063	1.55	3339	1.54
M1	3905	0.79	2515	0.74	3070	0.79	3462	0.93
M2	6149	1.34	4057	1.22	3423	1.36	3210	1.32
				Mandible				
I1	4434	0.81	2630	0.79	2647	0.77	3072	0.87
I2	4303	0.78	3510	0.82	2778	1.05	3036	0.88
C	4983	1.14	4626	1.26	4043	1.52	3214	1.61
P1	4755	1.37	3955	1.28	4098	1.38	2528	1.29
P2	4305	1.61	5425	1.50	4293	1.44	4027	1.45
M1	2825	0.79	2484	0.76	3118	0.77	3592	0.85
M2	3920	1.38	3880	1.23	3073	1.47	3918	1.33

[1] N represents the number of sides. All values in years and decimals.

or later in the lower (poverty level) economic grouping. Even though tooth emergence is later in Whites and earlier in Blacks, the within-race between-strata differences are very much the same for boys. Out of 28 combined-side comparisons (involving 56 teeth) 21 comparisons show delay in the lower socio-economic grouping. The stochastic chi-square for the observed ratio 21:7 as against the chance ratio 14:14 is 7.0, surely a highly significant difference in overall emergence timing for a per-capita income difference of $2200 or less.

In girls, both Black and White, and with systematically earlier ages at emergence, the dental delay associated with poverty is less clear. For the White girls, 9 out of 14 combined-side tooth-emergence comparisons are delayed in the lower (up to 1.49) income-needs grouping. The direction is the expected one, but the observed proportions (9:5) are not significant. For the Black girls the observed proportions (7:7) are exactly even, i.e., equal to chance. While for both sexes and both races, taken together, the income-associated emergence delay is quite evident (37:19 as against the chance proportions of 28:28, and with a chi-squared value of 5.78 by stochastic test) it is clear that the bulk of the income influence on permanent tooth emergence is evidenced in the boys.

Having completed the sign-tests and stochastic chi-squares, attention was then given to the relative magnitude of the emergence differences. This was done first by tooth, expressing the absolute differences (d) as standard scores or Z-scores, relative to the sex- and race-appropriate standard deviation (σ) for the total U.S.A. sample. Then the tooth-specific values of Z (the difference in standard scores) were pooled for all pairs of teeth, to assess the overall extent of relative (Z-score) dental delay.

As also shown in table 2, the average economic difference in tooth emergence timing was 0.13 Z-scores for the White boys, and a very similar 0.17 Z-scores for the Black boys. For girls, again comparing the lower (x — 1.49) and higher (2.25 — x) income-needs groupings, the Z-score differences were 0.09 in White girls and -0.03 for the Black girls. Taking as N one-half the total number of sides, the first three differences are highly significant, at any reasonable level of confidence. However, if N is taken as one-half the average number of sides for each of the 14 tooth pairs considered, the economic delay is significant only for boys. If further restricted to race-specific comparisons, the analysis thus based on the average number of individuals is significant only for the White boys, though not far from significance for the White girls.

These socio-economic differences in permanent tooth emergence, in the direction that would be expected in theory, apply to a pair of income needs and per-capita income groupings. One grouping is at poverty level, and the second grouping approximates the median U.S.A. income at the time of data collection. For a per-capita difference of approximately $2200, the difference in emergence timing is of the order of 0.15 standard deviations in boys, both Black (0.17 SD) and White (0.13 SD) and less than that for girls, both Black and White. Overall, the income-related delay in dental development is less than that similarly observed, and for the same population sample, for postnatal ossification timing (Garn et al., 73b). The lesser economic impact on tooth emergence is consistent with other data showing that dental development is less affected by other endocrine, metabolic and nutritional conditions (cf. Garn, Lewis and Blizzard, '65).

Now the lower socio-economic groupings in this study are not only less affluent, but they are shorter, they weigh less, they have less subcutaneous fat, lower hemoglobin levels, they are delayed in osseous (skeletal) maturation, and they differ in such economic indices as persons per room. Delayed emergence timing may therefore be viewed in terms of the total picture (cf. Garn and Russell, '71). At the same time it must be pointed out that the economic range here considered, from poverty level to U.S.A. median income, is not as wide a range as might be considered. At the upper end, median income is not middle class, i.e., mercantile and professional. Nor is the lower end equivalent to the rural populations of Central and South America, Asia, India or the Middle East. So the differences here reported in

TABLE 2

Economic impact on tooth emergence timing

	White children Income-needs group						Black children Income-needs group					
	Lower		Higher				Lower		Higher			
	N[1]	Mean	N[1]	Mean	d[2]	Z[3]	N[1]	Mean	N[1]	Mean	d[2]	Z[3]
						Boys						
Maxilla												
I1	1654	7.40	526	7.12	0.28	0.36	2508	6.96	46	6.79	0.17	0.21
I2	1660	8.51	799	8.10	0.41	0.41	2740	7.97	48	7.74	0.23	0.23
C	1756	11.45	1050	11.12	0.33	0.24	3004	10.97	98	10.42	0.55	0.34
P1	1830	10.63	968	10.67	−0.04	−0.03	2970	10.45	84	10.20	0.25	0.16
P2	1560	11.17	1050	11.30	−0.13	−0.09	3044	11.22	84	10.82	0.40	0.26
M1	1439	6.47	446	6.24	0.23	0.29	2359	6.25	36	6.12	0.13	0.17
M2	1500	12.45	886	12.52	−0.07	−0.05	2352	12.32	74	12.59	−0.27	−0.20
Mandible												
I1	1566	6.37	504	6.23	0.14	0.17	1739	6.11	41	5.56	0.55	0.71
I2	1566	7.54	754	7.34	0.20	0.26	2131	6.98	65	6.82	0.16	0.15
C	1798	10.61	945	10.46	0.15	0.13	3082	10.38	62	10.21	0.17	0.11
P1	1317	10.79	959	10.57	0.22	0.16	3119	10.40	84	10.43	−0.03	−0.02
P2	1480	11.47	1064	11.53	−0.06	−0.04	3277	11.18	84	10.73	0.45	0.31
M1	1013	6.36	418	6.35	0.01	0.01	2221	6.10	41	5.89	0.21	0.27
M2	1151	12.05	797	11.98	0.07	0.05	2339	11.96	86	12.38	−0.42	−0.29
Mean difference						0.13						0.17
						Girls						
Maxilla												
I1	1294	7.02	634	6.77	0.25	0.33	2356	6.75	56	6.77	−0.02	−0.02
I2	1520	7.95	890	7.99	−0.04	−0.04	2080	7.64	56	7.26	0.38	0.33
C	1453	10.78	1168	10.49	0.29	0.21	2167	10.66	40	10.28	0.38	0.24
P1	1479	10.18	1047	10.23	−0.05	−0.04	2388	10.06	96	10.05	0.01	0.01
P2	1640	10.87	921	10.83	0.04	0.03	1969	10.73	80	10.69	0.04	0.03
M1	1090	6.35	468	6.30	0.05	0.07	2211	5.95	38	6.61	−0.66	−0.71
M2	1357	12.01	687	12.01	0.00	0.00	2431	11.61	62	11.71	−0.10	−0.08
Mandible												
I1	1477	6.29	416	5.92	0.37	0.47	2052	5.87	50	5.66	0.21	0.24
I2	1435	7.15	626	7.05	0.10	0.12	1790	6.55	56	6.82	−0.27	−0.31
C	1532	9.84	833	9.69	0.15	0.12	2328	9.81	96	9.01	0.80	0.50
P1	1622	10.15	906	10.15	0.00	0.00	1716	10.09	96	9.41	0.68	0.53
P2	1339	10.96	1044	11.07	−0.11	−0.07	2814	10.75	84	10.93	−0.18	−0.12
M1	844	6.15	517	6.13	0.02	0.03	2050	5.67	38	6.57	−0.90	−1.06
M2	1308	11.50	838	11.49	0.01	0.01	2875	11.21	68	11.25	−0.04	−0.03
Mean difference						0.09						−0.03

[1] N represents the number of sides. All values in years and decimals.
[2] d represents the difference in years and decimals.
[3] Z represents the difference in years expressed in standard deviation units.

permanent tooth eruption timing do not constitute a comparison of extremes.

Besides the basic indication of the extent of dental delay that poverty produces, in less-affluent North Americans, these findings have several additional implications. They suggest, but do not prove, the magnitude of secular change that may have existed, or may be projected. Moving poverty-level boys and girls to median U.S.A. income may speed permanent tooth emergence by the magnitudes indicated by the differences. The observed differences, in emergence timing, do indicate the impropriety of comparing tooth emergence in truly malnourished populations elsewhere in the world with established "norms" or standards derived from middle class and private school boys and girls in the U.S.A. Yet the economic effect, as shown here, is sufficiently small as to indicate that contemporary emergence data may be applied to past populations without fear of gross or serious error, provided that clinical emergence (i.e., emergence through the gums) is not confused with alveolar eruption (movement through and above the alveolar process) as is still often done in paleontological studies and osteological investigations.

Finally it should be observed that the magnitude of economic delay in permanent tooth emergence timing is small in comparison with the racial difference in permanent tooth emergence. Poverty-level American Negro boys and girls are still advanced, dentally, over median-income White boys and girls (cf. Garn et al., '73a) and the difference increases only slightly when income-matched samples are compared, as in this study. Permanent tooth emergence remains an example of a growth parameter where population differences in timing or size are largely genetic but where careful analysis can elucidate the contribution of the environment.

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LITERATURE CITED

Abramowitz, M., and I. A. Stegun 1964 Handbook of Mathematical Functions. U.S. Govt. Printing Office, Washington.

Fess, L. R. 1965 Tooth eruption and nutrition: Cali, Columbia, December 1962–March 1963. Ph.D. thesis, Tulane University, New Orleans, Louisiana.

Garn, S. M., A. B. Lewis and R. M. Blizzard 1965 Endocrine factors in dental development. J. Dent. Res., *44:* 243–258.

Garn, S. M., J. M. Nagy and S. T. Sandusky 1972 Differential sexual dimorphism in bone diameters of subjects of European and African ancestry. Am. J. Phys. Anthrop., *37:* 127–130.

Garn, S. M., and A. L. Russell 1971 The effect of nutritional extremes on dental development. Am. J. Clin. Nutr., *24:* 285–286.

Garn, S. M., S. T. Sandusky, J. M. Nagy and M. B. McCann 1972a Advanced skeletal development in low-income Negro children. J. Pediat., *80:* 965–969.

Garn, S. M., S. T. Sandusky, J. M. Nagy and F. L. Trowbridge 1973a Negro-Caucasoid differences in permanent tooth emergence at a constant income level. Archs. Oral Biol., *18:* 609–615.

Garn, S. M., S. T. Sandusky, N. N. Rosen and F. Trowbridge 1973b Economic impact on postnatal ossification. Am. J. Phys. Anthrop., *38:* 1–4.

Garn, S. M., F. Wertheimer, S. T. Sandusky and M. B. McCann 1972b Advanced tooth emergence in Negro individuals. J. Dent. Res., *51:* 1506.

Klein, H., C. E. Palmer and M. Kramer 1937 Studies on dental caries. II. The use of the normal probability curve for expressing the age distribution of eruption of the permanent teeth. Growth, *1:* 385–394.

Orshansky, M. 1965 Counting the poor: Another look at the poverty profile. Soc. Sec. Bull., *28:* 3–29.

——— 1968 The shape of poverty in 1966. Soc. Sec. Bull., *31:* 3–32.

Ten-State Nutrition Survey 1968–1970 1972 U.S. Dept. of Health, Education, and Welfare, DHEW Publication No. (HSM) 72-8134, Center for Disease Control, Atlanta, Georgia.