Genetic Variation in Tooth Dimensions: A Twin Study of the Permanent Anterior Teeth*

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THE RELATIVE indestructibility of the teeth make them important structures in tracing human evolution, and thereby provide valuable morphological characters for both paleontological and genetic studies (Lasker 1950). In human evolution, tooth size has been importantly reduced, particularly in the front portions of the jaws (Hooton 1947). An hereditary basis for differences in tooth size has long been assumed in dentistry (Kingsley 1888), and has received considerable support from twin and family evidence (Korkhaus 1930; Lundstrom 1948), as well as from odontometric population studies (Dahlberg 1945; Moorrees, et al., 1957). Because of the potential value of the teeth for genetic studies of quantitative variation and human evolution, a twin study method will be utilized here in an effort to further our understanding of the genetic control of variations in the dimensions of the permanent anterior teeth.

THE STUDY SAMPLE

The twin subjects in the present study are a part of a larger study which has been in progress for several years at the Columbia-Presbyterian Medical Center (Osborne 1956), and will be reported in detail elsewhere. The total study population was drawn from a variety of sources in New York City, unselected as to sex and zygosity, ranging in age from 18 to 55 years, and obtained for the purpose of establishing a population of adult twin subjects in good general health. From this twin population, subjects were given appointments to come into the Division of Research of the School of Dental and Oral Surgery of the Faculty of Medicine, Columbia University, where they were seen by one of us and complete dental examinations given (S. L. H.). The average age of the group so studied was 27 years and included 33 pairs of monozygotic twins (21 female and 12 male), 21 pairs of like sex dizygotic twins (16 female and 5 male). All subjects were Caucasian, predominantly of Northwest European descent, and approximately equally divided between Jews and Non-Jews.

METHODS

The diagnosis of twin zygosity has been based upon proving dizygosity, first by a proven difference in a blood group factor, and then by adding reliable morphological characters for those pairs agreeing in all factors tested for in extensive blood studies.

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These criteria, as well as the method of diagnosis, will be presented in detail in a forthcoming publication.

For the measurement of the teeth quick setting stone casts were prepared from alginate impressions of the maxillary and mandibular teeth of each subject. Measurements of the widest mesio-distal diameter of each of the six maxillary and six mandibular anterior teeth of the permanent dentition were obtained from the models by means of a finely pointed sliding caliper, fitted with a vernier scale which permitted readings to the nearest 0.1 mm. The legs of the caliper were placed at the contact points and the instrument held parallel to the occlusal surfaces of the teeth as the individual tooth was measured. Teeth which had been restored with porcelain or acrylic jackets, and those which had either carious lesions or restorations which affected a contact point were eliminated from the study. All casts were given random code numbers, and measured individually, not as casts of twin pairs.

RESULTS

The first objective in a twin analysis is to test for the presence of a measurable component of genetic variability by comparison of the average of the differences between the two members of monozygotic twin pairs to the average of the differences between the two members of dizygotic twin pairs. This comparison has been made on the basis of the mean intrapair variances. The mean intrapair variance being $(\Sigma x^2)/2n$, where x is the difference between the two members of a twin pair for the mesio-distal tooth diameter of a given tooth, and n is equal to the number of twin pairs. From these mean intrapair variances, variance ratios have been calculated and the F Distribution used to obtain the probability level of these ratios. Heritability estimates have not been calculated because of reservations concerning both the genetic and statistical meaning of these estimates with twin data. Furthermore, heritability estimates yield no information of importance with human material which is not provided by the probability levels of the variance ratios.

To permit the assessment of measurement error, and to determine whether monozygotic intrapair variances demonstrate a measurable component of environmentally conditioned variability, a series of duplicate measurements were obtained. The models of 30 subjects were selected at random and duplicate measurements made of all the twelve teeth studied. A measurement error variance was calculated, where x is equal to the difference between the first and second measurements, and n is equal to the number of casts measured twice. The mean measurement error variances obtained ranged from 0.003 for the maxillary right central incisor to 0.008 for the maxillary right canine. In each instance, the mean measurement error variance is found to be significantly less ($P<.001$) than the monozygotic mean intrapair variance.

In orthodontic studies of tooth dimensions, where interest is mainly centered upon the amount of tooth material present, the average of the dimensions of the tooth on the right and left side is customarily used (Moorrees 1951). In genetic and anthropological studies it has been common practice to base the analysis on the teeth of one side. (Almost invariably a certain amount of asymmetry is present, and while this may be of considerable interest, it constitutes a special and extremely complex problem). For our present purpose, the analysis is based entirely upon the teeth of the right side. The data for males and females were analyzed separately, but save for factors relating to assymmetry, there were no significant sex differences. In both Lunstrom's (1948) and Seipel's (1946) twin data no sex differences were found, therefore, in the present analysis males and females have been combined.

The mean intrapair variances of monozygotic and dizygotic twin pairs, together with the ratios of these variances, are presented in table 1. The strong genetic component of variability for mesio-distal tooth dimensions, particularly for the incisors, is in agreement with the findings of Lundstrom (1948), Korkhaus (1930), and others. The relatively large mean dizygotic variance of the maxillary lateral incisors is also in agreement with the previous twin data. The comparatively small component of genetic variability for the maxillary canines accords well with odontometric population data. The monozygotic, or non-genetic, variance of the maxillary canine is similar to that of the incisors, while the dizygotic variance is considerably smaller. The apparently lower genetic variability for the canines is compatible with the hypothesis of their relative stability in human evolution as suggested by Dahlberg (1949) in his adaptation of Butler's "field concept".

It has been well established that certain points in the dentition are more variable than are others (Moorrees 1957). In view of the apparently strong genetic component

TABLE 1. MONOZYGOTIC AND DIZYGOTIC MEAN INTRAPAIR DIFFERENCES IN MESIO-DISTAL CROWN DIAMETERS OF THE PERMANENT ANTERIOR TEETH†

	n	Variance	F Ratio
		a. Right Maxillary	
I_1			
MZ	30	.035	3.51**
DZ	18	.123	
I_2			
MZ	29	.038	8.50***
DZ	18	.323	
C			
MZ	29	.039	2.23*
DZ	18	.087	
		b. Right Mandibular	
I_1			
MZ	26	.015	5.53***
DZ	15	.083	
I_2			
MZ	29	.018	6.17***
DZ	17	.111	
C			
MZ	29	.030	3.27**
DZ	19	.098	

* $P < .05$; ** $P < .01$; *** $P < .001$.

† Males and females combined.

of variability for mesio-distal dimensions, the interrelationship of the dimensions of the permanent anterior teeth would be of interest. When the different teeth are studied within the same individual it is exceedingly difficult to analyze the true nature of their interrelationship because of the common environment to which they are subjected. By a modification of the twin method, however, it becomes possible to determine to what extent different traits or measurements, (in this instance mesio-distal tooth dimensions), are independent, mechanically, physiologically, or genetically (Lerner 1950). This modified twin method will be referred to as a "cross twin analysis". By this method the interrelationship between two teeth in the same individual can be compared to the interrelationship between one of these teeth in Twin A and the other tooth in Twin B, the co-twin. In the present study one member of each twin pair has been taken at random and his central incisor (I_1) compared to his lateral incisor (I_2) and the lateral incisor then compared to the canine (C) to determine the relationship between adjacent teeth within the same individual. The central incisor of the individual taken at random has then been compared to the lateral incisor of the co-twin, and the lateral incisor to the co-twin's canine for the cross twin analysis.

In monozygotic twins the cross twin values provide a measure of the importance of factors acting alike upon morphologically adjacent teeth in two different, though genetically identical, individuals. Comparison of the cross twin results to those obtained within individuals provides a measure of the relative importance of the within individual environment. A comparable analysis in dizygotic twins tests the "co-relation" or mutuality of relationship between these teeth in genetically different individuals. Comparison of the latter with the observations made within individuals and between the two members of monozygotic pairs indicates the relative importance of the genetic factors which are acting alike upon the mesio-distal diameters of adjacent teeth.

The correlation coefficient is an appropriate method for measuring the "co-relation" or association between two variates and has been employed here. To assure reliability of results by this method certain precautions have been taken. (i) The only comparisons made are those which previous odontometric and developmental studies have indicated to be meaningful. The correlation coefficient has not been used as a method of searching for statistically significant associations. (ii) Conclusions have been based upon the value of the calculated probabilities, rather than upon the magnitude of the correlation coefficient or their standard errors (Fisher 1954, p. 195). (iii) Interpretation as to the relative importance of the correlations of different sizes is based upon values of z, rather than upon values of r (Fisher 1954, p. 201).

In both maxilla and mandible the individual and the monozygotic cross twin correlations between adjacent teeth are highly significant (table 2). From this it is clear that large central incisors tend to go with large lateral incisors, and large lateral incisors tend to go with large canines. The fact that all the monozygotic cross twin correlations are highly significant further indicates that the association between adjacent teeth for mesio-distal dimensions is not merely a consequence of within individual mechanical or physiological influences. The comparability of the individual and monozygotic cross twin z values supports this conclusion. While the

TABLE 2. CORRELATIONS BETWEEN THE MESIO-DISTAL CROWN DIMENSIONS OF THE PERMANENT ANTERIOR TEETH

	Comparison	n	r	t†
	a. Right Maxillary			
	I_1 with I_2			
MZ	Individual	27	0.546**	0.850
	Cross Twin	28	0.694***	1.384
DZ	Cross Twin	20	0.397	2.270*
	Individual	20	0.834***	
	I_2 with C			
MZ	Individual	27	0.692***	0.671
	Cross Twin	28	0.578**	0.886
DZ	Cross Twin	17	0.349	1.792
	Individual	20	0.766***	
	b. Right Mandibular			
	I_1 with I_2			
MZ	Individual	26	0.803***	0.075
	Cross Twin	26	0.795***	0.949
DZ	Cross Twin	18	0.647**	1.205
	Individual	18	0.837***	
	I_2 with C			
MZ	Individual	28	0.850***	0.502
	Cross Twin	29	0.806***	3.030**
DZ	Cross Twin	17	0.116	1.551
	Individual	20	0.589**	

* $P < .05$; ** $P < .01$; *** $P < .001$.
† t is calculated for the difference of the values of z.

smallest z values are consistently obtained in the dizygotic cross twin correlations the dizygotic cross twin correlation of mandibular central incisor with mandibular lateral incisor is statistically significant. Apparently there is either little genetic variability or independence of affect in the genetic factors acting upon the mandibular incisors. Again, comparison of z values gives support to the conclusions based upon the significance of the cross twin correlation coefficient.

The dizygotic cross twin correlation coefficients for maxillary I_1 with maxillary I_2, maxillary I_2 with maxillary C, and mandibular I_2 with mandibular C, are the only correlations which fail to reach statistical significance. These dizygotic cross twin correlations suggest that some genetically conditioned independence of mesiodistal dimensions may be present for these teeth, in addition to a common size factor as previously discussed. The relatively small z transformations obtained for these three dizygotic cross twin correlations are in agreement with such a suggestion. The statistically significant difference between the maxillary I_1:I_2 dizygotic cross twin and individual values ($P = 0.02 - 0.05$), and between the mandibular I_2:C monozygotic and dizygotic cross twin z values ($P = 0.002 - 0.005$) gives further evidence of some genetically conditioned independence of maxillary I_1 and I_2, and mandibular I_2 and C in addition to some size influence. While the z transformations for the maxillary lateral incisor and canine do not provide significant differences in the present data, it is probable that these teeth are also partly independent in view of the z values obtained.

DISCUSSION

The present data confirm previous findings by Lundstrom and others of a strong genetic component of variability in mesio-distal tooth dimensions for the permanent anterior teeth, particularly for the four incisors studied. Some support is also given to the hypothesis of a relatively small genetic variability of the canines.

The statistically significant correlation coefficients within individuals, and also in the monozygotic cross twin comparisons, must be interpreted as indicating some genetic control of tooth size common to adjacent teeth, and perhaps even of general tooth size in the anterior dentition. The significant differences between the z transformations, as well as the correlations obtained in the dizygotic cross twin analysis gives evidence that other genetic factors are also affecting the mesio-distal diameters of the maxillary lateral incisor, and the maxillary and mandibular canines. The results of this cross twin analysis is of particular interest in light of the developmental history of the permanent anterior teeth as presented by Schour (1940, 1955). While initation of all the permanent anterior teeth begins at 5–6 months in utero, completion of size growth of the different teeth in this group occurs at different times. The maximum size of the maxillary central incisors and the mandibular central and lateral incisors is established by 3 to 4 months after birth, approximately one month later in the case of the canines, and not until 10–12 months after birth for the variable upper lateral incisors. The present analysis now gives evidence that the size of these teeth is under different genetic control. It is therefore possible that for these teeth there is an association of time, size, and genetic control. Not only may the anterior tooth dimensions provide genetic differences with a recorded time of developmental effect, but also, as the monozygotic twin intrapair differences show a measurable environmental component of variability it may be further possible to use the anterior tooth dimensions for studying specific growth disturbances in monozygotic twins (Price 1950).

SUMMARY

A strong component of genetic variability for the mesio-distal tooth dimensions of the permanent anterior teeth is confirmed by the present data. By the use of a cross twin analysis, support is obtained for a hypothesis of a genetic control for general tooth size, as well as for other genetic factors which in addition affect the size of the maxillary lateral incisors and the canines. Developmental evidence supporting this hypothesis is discussed.

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