Hereditary Factors In Tooth Dimensions, A Study Of The Anterior Teeth Of Twins*

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INTRODUCTION

It has long been assumed that tooth breadth is a characteristic controlled by hereditary forces. Kingsley[1] expressed one of the prevailing orthodontic concepts of the nineteeth century when he wrote, "The cause of irregularities of teeth is . . . sometimes due to the inheritance of large teeth out of all proportion to the size of the inherited jaw." This view is still widely held today. It is generally accepted that, while harmonious relationship between tooth dimensions and arch length results in the development of a satisfactory alignment and optimum occlusion of the teeth, disproportion between the two elements predisposes toward crowding or spacing in the arch[2].

Greater emphasis has been placed on assessing the ratio, or proportional relationship, between the size of teeth and the length of the bony arch [2-9], and on the relationship between the upper and lower teeth[10-13], than upon the hereditary aspects of either tooth or bony arch dimensions. As these analyses have in common the evaluation of differences in relative proportions, either of teeth to the bony arch or of teeth to each other, it becomes of fundamental interest to establish biometrically the range of variation of each factor in the ratio.

The quantitive variation which occurs in a complex morphological characteristic such as mesio-distal tooth dimension is influenced by both hereditary and environmental forces. The effects of a non-genetic factor (diet) on the size of molar teeth in rats has recently been demonstrated by Paynter and Grainger[14] and indicates that this is one environmental aspect of tooth development which requires further investigation.

The present communication is concerned with the analysis of the quantitative hereditary variation which occurs in one element of the tooth size/bony arch ratio, the mesio-distal tooth dimensions of the six maxillary and six mandibular anterior teeth.

THE STUDY METHOD

The twin-study method has been used in the investigation of hereditary characteristics in man since Galton's time[15]. The method has been employed occasionally in dental and orthodontic research, perhaps most frequently for the investigation of inherited variation in tooth size and occlusion[16-20].

By definition, a study of tooth dimensions is a study of quantitative variation. The problem is quite different than one of whether a given tooth is or is not inherited as might be the case, for example, in a qualitative study of

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congenital tooth absence. Rather, it is a matter of whether the individual variations in tooth dimensions have a measurable hereditary component. In order to evaluate this type of a genetic problem ideally, an investigative procedure is required in which genetic variation is a known factor, and in which other contributory variables can either be controlled or measured.

The twin study method more nearly satisfies these exacting requirements than any other method presently available. In comparing the two members of monozygotic twin pairs whose coefficient of genetic relationship is (by definition) equal to 1.0, indicating identical genetic endowment in both members of the pair, any observed difference in tooth dimension must be due to factors other than heredity.

When both members of a monozygotic twin pair are studied simultaneously, differences in developmental stage are eliminated; as monozygotic twins must be of the same sex, sex differences are automatically excluded. In pairs where both members have been raised in the same home, major nutritional and other environmental factors are similarly reduced to a practical minimum for human studies. The remaining causes of variation become developmental or health differences, which can be determined from observing other physical attributes and by obtaining comparable health (including dental) and developmental histories, and measurement on experimental error.

In the case of dizygotic twins, the average coefficient of genetic relationship is equal to 0.5, which is the same as that for ordinary single-born siblings. Consequently, observed differences between the two members of a dizygotic twin pair result from the same influences which affect monozygotic twins plus a difference in one-half of their total heredity. When a study of dizygotic twins is carried out to parallel the one outlined above for monozygotic twins, a comparison of the average of the differences for monozygotic and dizygotic twins will provide a test of the observed effect of a difference in one-half the total hereditary constitution.

The Study Sample

The subjects utilized for the present investigation are from a larger study (to be reported in detail elsewhere) which has been in progress for several years at the Columbia-Presbyterian Medical Center[21].

The total study group consists of Caucasian twins drawn from a variety of sources in New York City, unselected as to sex and zygosity, with an age range from 18 - 55 years, and obtained for the purpose of establishing a sample of adult twin subjects in good general health.

Tooth dimensions were obtained for 54 pairs of like-sexed twins with an average age of 27 years. This group included 33 pairs of monozygotic twins (21 female and 12 male), and 21 pairs of dizygotic twins (16 female and 5 male).

Methods

The central problem in any twin study is the accurate diagnosis of zygosity. The method employed in the present study was based upon proving *dizygosity*, first by a proven difference in a blood group factor, and in addition by other reliable characteristics such as eye color, ear form and dermal patterns for all like-sex pairs which agreed in all their blood factors. The advantages of this method are: (1) it provides a known direction to any possible error in diagnosis, and (2) it tends to underestimate rather than overestimate the inheritance factor for any characteristic under investigation. It may be assumed, therefore, that the conservative nature of the method provides ample insurance that significant results are not attributable to chance errors in the diagnosis of zygosity. A detailed discussion of this method may be found elsewhere[22]. *Measurement Methods.* 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 incisal 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.

Duplicate measurements were made of all of the twelve teeth studied utilizing the models of thirty subjects selected at random. These double determinations were used to assess the measurement error.

Results

Monozygotic twins. The average differences observed between the members of monozygotic twin pairs are given in Table 1. In the maxillary arch it is the left central which shows the smallest mean difference, 0.17 mm., while the left lateral has the greatest, 0.24 mm. For the mandibular teeth these differences range from 0.10 mm. for the left central to 0.21 mm. for the left canine.

Dizygotic twins. Table 1 also presents the average differences observed in the

TABLE I

Comparison of Mean Intra-pair differences in Mesio-Distal Tooth Dimensions between Monozygotic and Dizygotic twins.

MAXILLARY TEETH

	n (pairs)	Mean diff. (mm)	S.D.	P†
Right				
I_1				
Monozygotic	30	.20	.18	<.001*
Dizygotic	18	.37	.34	
I_2				
Monozygotic	29	.22	.17	>.001*
Dizygotic	18	.56	.59	
C				
Monozygotic	29	.23	.15	<.025
Dizygotic	18	.33	.26	
Left				
I_1				
Monozygotic	31	.17	.14	>.001*
Dizygotic	16	.37	.28	
I_2				
Monozygotic	31	.24	.20	>.005*
Dizygotic	16	.42	.33	
C				
Monozygotic	26	.19	.15	<.25
Dizygotic	14	.14	.18	

MANDIBULAR TEETH

	n (pairs)	Mean diff. (mm)	S.D.	P†
Right				
I_1				
Monozygotic	26	.13	.12	>.001*
Dizygotic	15	.29	.29	
I_2				
Monozygotic	29	.16	.11	>.001*
Dizygotic	17	.35	.33	
C				
Monozygotic	29	.20	.14	<.001*
Dizygotic	17	.38	.24	
Left				
I_1				
Monozygotic	27	.10	.08	>.001*
Dizygotic	18	.35	.26	
I_2				
Monozygotic	28	.14	.16	>.005*
Dizygotic	15	.30	.22	
C				
Monozygotic	26	.21	.21	<.05
Dizygotic	21	.31	.25	

†A variance analysis was employed and P values were obtained by means of Fisher's F test (variance ratio).

*Statistically highly significant.

tooth breadths of the dizygotic twins. The maxillary teeth show a range of differences from 0.14 for the left canine to 0.56 for the right lateral. In the mandible the range is from 0.30 mm. for the left lateral to 0.38 for the right canine.

Comparison of the standard deviations provides a familiar estimate of the variability of the mean differences obtained between the members of the twin pairs. For the monozygotic twins the S.D. of the six maxillary teeth show a small range, from 0.14 to 0.20; while the mandibular S.D. vary between 0.08 and 0.21.

In the dizygotic twins the S.D. of the maxillary teeth fall into a pattern. Those for the central and lateral teeth show evidence of appreciably greater variability than either of the canines. In the lower arch this also holds true on the right side, while on the left the canine forms an exception.

Difference Between Categories

Comparison of the mean intra-pair differences observed between members of the twin pairs in the separate categories provides a measure of the degree to which monozygotic twins are more alike than dizygotic twins. The larger the difference between these two values, the greater is the hereditary factor in the variability of the particular tooth. As has been noted, none of the teeth measured show large mean variations between the members of monozygotic twin pairs. The mean differences are much greater between members of dizygotic twin pairs.

By employing a variance analysis based upon the mean intra-pair differences it becomes possible to obtain an efficient and statistically exact test of the significance of these differences. Fisher's variance ratio, or F test, has been used for tests of statistical significance in this study. (For details of the statistical methods employed see Osborne[22], et. al.)

When such a test is applied, the most prominent feature of these data is the strong genetic component of variability of the four maxillary and four mandibular incisor teeth. The differences between members of monozygotic and dizygotic twin pairs are statistically highly significant for all of these teeth. The probability values range from $P = >.005$ to $P = <.001$.

The canine teeth, on the other hand, give evidence of much less of an hereditary component of variability. The mean intra-pair values do not show statistically significant intra-pair differences between the twin categories with the single exception of the mandibular right canine. This low measurable hereditary variability, especially in the upper canines, is not the result of an increase in non-genetic (environmental) influence, but reflects an actual lack of genetic variability observed in these teeth between the members of dizygotic twin pairs.

Environmental Variation

Non-genetic variation for each of the twelve teeth studied may be further analyzed by comparing the mean differences observed between the members of monozygotic twin pairs. Environmental variation is about twice as great in the maxillary central and lateral incisors as in the corresponding mandibular teeth. The canine teeth demonstrate non-genetic variability comparable to that of the incisors.

Sex and asymmetry components affect non-genetic variability and may also be measured by comparing the monozygotic twins (Table 2). It is apparent from the data that these factors accumulate particularly in the maxillary left central, mandibular left canine and mandibular left lateral, resulting

TABLE II

Male - Female Intra-pair Differences in Mesio-Distal Tooth Dimensions (Monozygotic Twins)

	RIGHT				LEFT			
	n (pairs)	mean difference (mm)	S.D.	P	n (pairs)	mean difference (mm)	S.D.	P†
Maxillary Teeth								
I_1								
Male	12	.23	.17	<.25	12	.26	.15	<.005*
Female	18	.18	.19		19	.12	.10	
I_2								
Male	10	.27	.17	>.25	12	.23	.25	<.25
Female	19	.20	.16		19	.24	.16	
C								
Male	10	.23	.19	<.25	11	.16	.16	<.25
Female	19	.24	.13		15	.21	.14	
Mandibular Teeth								
I_1								
Male	9	.19	.12	<.05	11	.11	.08	.25
Female	17	.09	.11		16	.09	.07	
I_2								
Male	11	.15	.10	<.25	10	.17	.22	.025
Female	18	.12	.11		18	.12	.12	
C								
Male	10	.18	.16	<.25	8	.34	.25	.005*
Female	19	.21	.14		17	.14	.14	

in statistically significant sex differences in those teeth. Our data indicate that this is unilateral in nature and tooth specific.

Discussion

Earlier odontometric studies of twins give an approximate indication of the variability of the anterior teeth, but tests of statistical significance cannot be made from the data as published. Nevertheless, both Reif[16] and Korkhaus[19] found the largest intra-pair differences in size (by percentage) occurred in the maxillary right lateral teeth. This genetic variability is confirmed in our data with a high degree of statistical significance.

Lundström[20], in his twin study, also obtained the largest coefficient of variation in the maxillary lateral incisors and additional evidence of the great variation in mesio-distal width of the laterals is provided by odontometric population studies[3 23 25].

By comparison with the incisor group, the canine teeth demonstrate very little measurable genetic variability. This finding confirms previous reports. Lundström's twin data indicate a lower coefficient of variation for the canines than for the incisor teeth and odontometric population studies agree on the low degree of canine variability.

The comparatively low genetic component of variability demonstrated in the canine tooth width is of interest in numerous ways. Functionally, this tooth occupies a strategic location in the dental arch as the link which connects the premolar-molar series with the incisors. In prosthetic dentistry it is an extremely important dental unit owing to its large area of periodontal membrane attachment. In addition, the maxillary canine has an esthetic function in preserving facial contours, acting as a support for the corner of the lip. To the orthodontists, the canine is the "keystone in its lateral half of the dental arch[26]," a role which demands relative constancy in size and form. Dahlberg[27 28], in his adaptation of Butler's[29] field concept of the human dentition, considers the canine "morphologically stable as concerns expression and retention of ancestral patterns." The limited genetic variability of the canine observed in this study is compatible with Dahlberg's hypothesis of a comparatively slow rate of evolutionary change, or "stability" in this tooth.

With regard to bilateral asymmetry noted in the data, it appears that the environmental variability of teeth on the left side, particularly the maxillary central, mandibular canine and mandibular lateral, is sex-influenced. It is the significantly greater male variability which produces this right-left discrepancy in the mandibular canine ($P = .025$ when the right and left sides are compared). That the sex influence operates more strongly on the left side has also been found in dermatoglyphic patterns[30], which suggests that there may be some general sex-influenced asymmetry mechanism operating at a developmental level. Significant sex differences in canine tooth dimensions have been reported in recent population studies[24 25].

Analysis of the data reported offers a partial explanation for the inconsistent results in treatment planning obtained with various tooth size/bony arch ratios[9 31]. As has been pointed out[6], it may not be possible to attain high precision in predictive methods based on tooth size. When mesio-distal tooth dimensions are used to establish orthodontic diagnosis ratios, the findings of this study suggest that the anterior teeth be considered as two separate groups, the "variable" incisors and the relatively "stable" canines.

Summary

1. Hereditary variation in mesiodistal tooth dimensions is analyzed by means of the twin-study method, utilizing a group of fifty-four pairs of adult, like-sexed Caucasian twins.
2. Genetically conditioned variations of a highly significant nature occur in eight of the twelve anterior teeth studied. The canine teeth demonstrate a relatively low hereditary component of variability.
3. Sex and asymmetry factors appear to play a part in the variation observed in the maxillary left central, and mandibular left canine and lateral teeth.

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