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ORIGINAL RESEARCH

Heritability of Thirty Cephalometric Parameters on Monozygotic and Dizygotic Twins: Twin Study Method

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ABSTRACT

Genetic mechanisms are already predominant during embryonic craniofacial morphogenesis, but environment is also thought to influence dentofacial morphology postnatally, particularly during facial growth. A better understanding of the relative effects of genes and environment on dentofacial and occlusal parameters should improve our knowledge on the etiology of orthodontic disorders and therefore also on the possibilities and limitations of the orthodontic treatment and treatment planning. The aim of the present study is to explore the genetic and environmental influence on craniofacial dimensions in a group of 19 pairs of twins using the twin study method. The twin study carried out here clearly indicates that craniofacial matrix is under substantial genetic control and the redirection of a basic growth pattern may be modified only within biological limits which are harmonious for the patient.

Keywords: Monozygotic, Dizygotic, Twin method, Cephalometric measurements, Craniofacial structure.

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INTRODUCTION

The science of genetics is concerned with the inheritance of traits; whether normal or abnormal, and with the interaction of genes and the environment. This latter concept is of particular relevance to medical genetics, since the effects of genes can be modified by the environment.[1]

Consideration of the heritability of a particular feature or trait requires a consideration of relationship between genotype and phenotype. Genotype is the genetic constitution of an individual and may refer to specified gene loci or to all loci in general. An individual's phenotype is the final product of a combination of genetic and environmental influence. The proposition of the phenotypic variance attributable to the genotype is referred to as heritability.[2]

Twins as first suggested by Galton form a unique tool to evaluate the interactions between 'nature' and 'nurture'. The scientific study of human twin began in the 1870's when Sir Francis Galton published a series of articles arguing that heredity (Nature) was stronger factor than environment (Nurture) in the respective characteristics of twins.[3]

Twins occur in about 1 in 85 human birth. Twins come in two types: Fraternal or dizygotic and identical or monozygotic (the difference between the two types of twins stems from a difference in how they begin life). Fraternal or dizygotic twins fertilize from two separate eggs sharing an average of 50% of their genetic material whereas monozygotic twins fertilize from a single egg that later splits into two, sharing 100% of their genetic material.[4,5]

Comparison of monozygotic and dizygotic twins is frequently used to partition research of quantitative traits into environmental and genetic factors.[1,6]

Twin study method is one of the most effective methods available for investigating genetically determined variables in orthodontics, as well as in other medical fields.[7,8]

AIMS AND OBJECTIVES

The aim of the present study is to explore the genetic and environmental influence on craniofacial dimensions in a group of 19 pairs of twins using the twin study method.

The main objectives of the present study were:

1. To review current knowledge on the heritability pattern of craniofacial structures that are relevant to clinical orthodontic practice in monozygotic and dizygotic twins.
2. To test as many cephalometric measurements as possible: Linear, angular, skeletal, dentoalveolar vertical, horizontal, anterior and posterior parameters to evaluate the amount of heritability for each craniofacial structure.

MATERIALS AND METHODS (FIGS 1A TO 2B)

The study was undertaken in the Department of Orthodontics, Government Dental College and Hospital, Hyderabad. The sample consisted of 19 pairs of twins, residing in twin cities of Hyderabad and Secunderabad with ages ranging from 14 to 25 years. Of the 19 pairs of twins 12 were determined to be monozygotic or identical and seven were dizygotic or fraternal. Among the 19 pairs of twins 13 pairs were of males, four pairs were of females and two pairs were of opposite sex. Among the 12 pairs of monozygotic twins, nine pairs were of males and three pairs were of females. Among the dizygotic pairs, four pairs are male and two pairs comprised of male and female and one pair was female.

The criteria applied for selection of the subjects for inclusion in this study were:

1. The subjects for the study were residents of Hyderabad and Secunderabad.
2. Twins were all above the age of 14 years.
3. No history of previous orthodontic therapy.

After selecting the subjects, following records were:

1. Facial photographs
2. Fingerprints
3. Blood sample
4. Lateral cephalogram

Past history of the twin pairs was taken and the presence of any habits was noted.

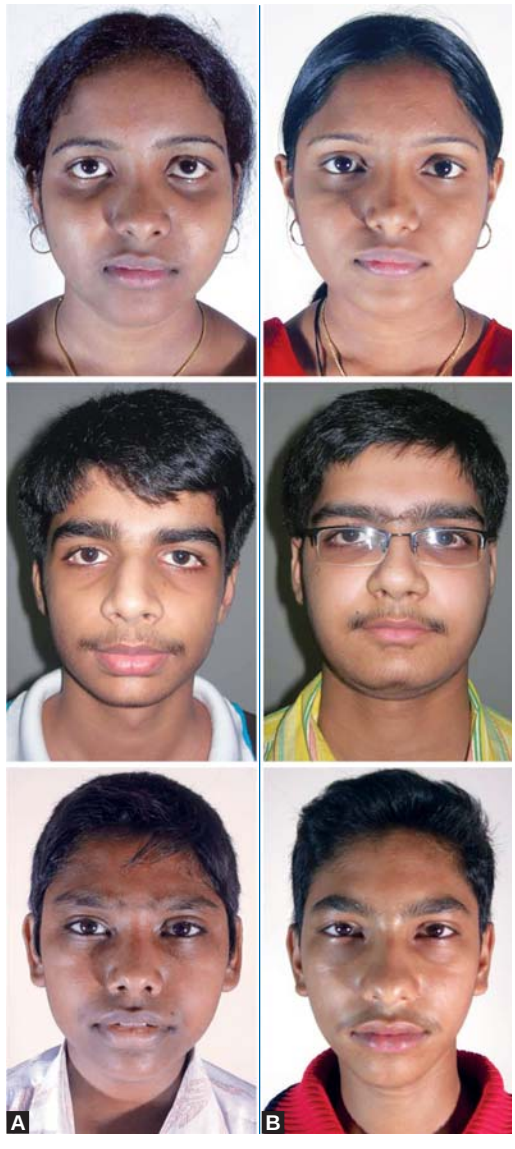
The investigations carried out on the entire sample are described under two headings:

1. *Investigations for determining zygosity of twins:* The methods already established by other researchers for determining zygosity so as to segregate monozygotic from dizygotic twins were carried out.
2. Investigations for collecting data on possible craniofacial variations.

The subjects in the study were systematically analyzed by using the following steps:

1. Determination of zygosity of twins
2. Cephalometric analysis of twins (Fig. 3)

Figs 1A and B: Monozygotic twins



Figs 2A and B: Dizygotic twins

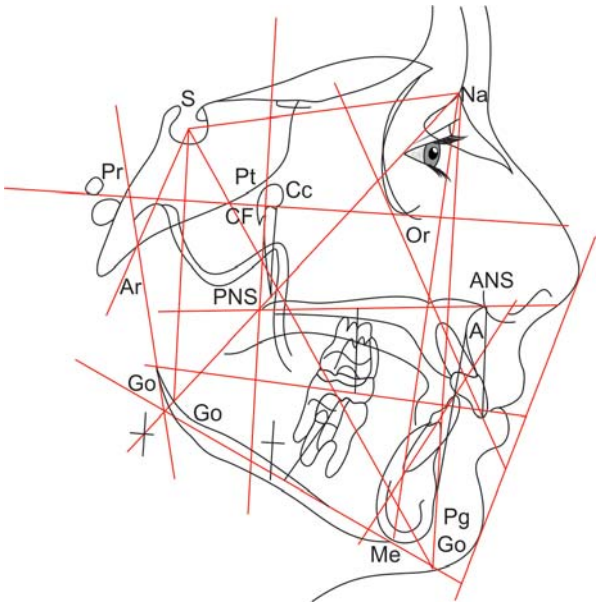


Fig. 3: Lateral cephalometric parameters used in the study (TAFH: Total anterior facial height; UAFH: Upper anterior facial height; LAFH: Lower anterior facial height; PFH: Posterior facial height; LI-A-POG: Lower incisor to A-Pog linear; LIP-E line: Lip to esthetic line; FP-Pt A: Facial plane to point A; UI-PP: Upper incisor to palatal plane; 1st M-MP: Mandibular 1st molar to mandibular plane; LI-MP: Lower incisor edge to mandibular plane; MP: Mandibular plane; N-S-AR: Saddle angle; IIA: Interincisal angle; LI-A-POG: Lower incisor to A-pog angular; FP-FH: Facial plane to Frankfort horizontal plane; MP-FP: Mandibular plane to facial plane; PP-MP: Palatal plane to mandibular plane; N-S-GN: Y-axis; SN-MP: Anterior cranial base to mandibular plane; UI-SN: Upper incisor to anterior cranial base)

Investigations for Determining Zygosity

Zygosity determination is an important part of any study dealing with twins. Zygosity can be determined by external trait, dermatoglyphics, serologic examination, genetic typing.

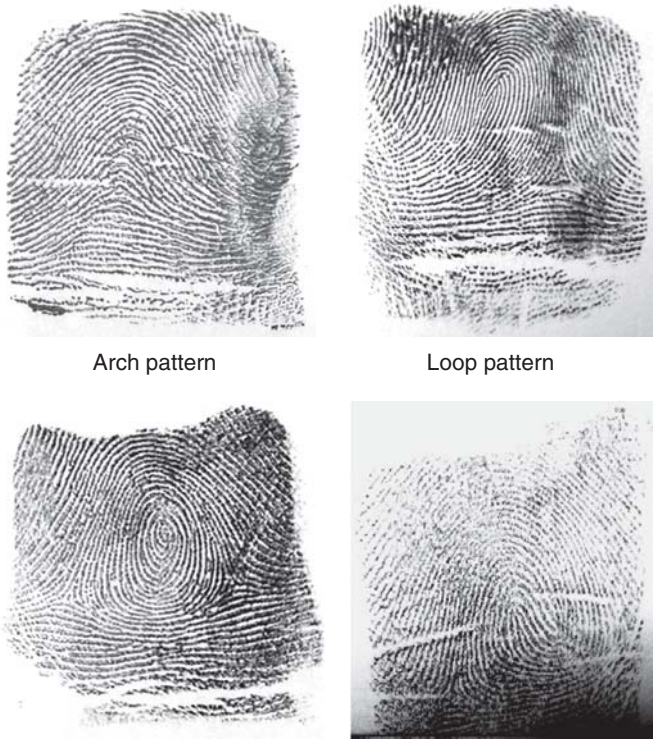
Dermatoglyphics

Procedure for recording fingerprints (Figs 4 and 5): All fingerprints were recorded and analyzed. The chief requirements are a tube of printer's ink or duplicating ink (Kores, India), a roller, an inking plate and blank white sheets for recording the prints. The roller used was about 6 inches long and 2 inches in diameter.

Procedure

1. The subject's fingers are thoroughly cleaned before each recording.
2. The inking plate and roller are cleaned with solvent denatured alcohol after every use.
3. The white sheets used to record prints were of standard A_4 size.
4. A small daub of ink is placed on the inking slab and thoroughly rolled with the roller until an even pigment covers the entire surface.

Fig. 4: Armamentarium used in finger print analysis



Arch pattern | Loop pattern

Whorl pattern | Composit

Fig. 5: Digit patterns

5. There are two kinds of fingerprint impressions made on each sheet. The upper 10 prints are taken individually of thumb, index, middle, ring and little finger of each hand by rolled impression technique.
6. In taking rolled impressions the bulb of the finger is placed at right angles to the surface of the inking plate. The finger is then turned or rolled until the bulb faces in the opposite direction. The finger must be inked evenly from the tip to below the first joint. By pressing the finger lightly on the sheet and rolling in the same manner, a clear rolled impression of the finger pattern surface is obtained. Inking, rolling and printing each finger

separately starting with the right thumb and then the other fingers obtain good results.

7. It has been taken care that no resistance was attempted on the part of the subject while taking the impression.
8. Pressing all the fingers of the hand on the inking slab and then on the paper makes the plain impressions.

Investigations for Collecting Data on Possible Craniofacial Variations

Lateral cephalograms were taken and analyzed for each subject.

Analysis

Heritability (H) is defined as the proportion of the phenotypic variance attributable to genetic sources. To find out the intrapair differences one number of the pair was taken as d1 and the other as d2. This was carried out for all parameters in both monozygotic and dizygotic twin pairs. From this mean variance was calculated. Using the mean variance F-ratio, heritability (H) and standard error was calculated.

Formulas:

$$V_{MZ} = \frac{d_1^2}{2N_1}$$

$$V_{DZ} = \frac{d_2^2}{2N_2}$$

$$F = \frac{V_{DZ}}{V_{MZ}}$$

$$\text{Heritability (H)} = \frac{V_{DZ} - V_{MZ}}{V_{DZ}}$$

$$V(H) = \frac{2 \cdot N_2^2 (N_1 - 1)(N_1 + N_2 - 4)}{N_1^2 (N_2 - 3)(N_2 - 5)} \cdot 1/F^2$$

$$SE(H) = \sqrt{V(H)}$$

V_{MZ} = mean variance in monozygotic twin pairs
V_{DZ} = mean variance in dizygotic twin pairs
N = number of observations
H = heritability
V (H) = variance of heritability
SE (H) = standard error

RESULTS

The results have been put forth in the following order:

1. Results related to zygosity determination: Tables 1 to 3
2. Results obtained from statistical analysis of cephalometric variables (Tables 4 to 9).

Dermatoglyphic Analysis (TABLE 3)

This included a comparison of the digit patterns. The findings are summarized as under following sample like:

In the following 19 samples, 12 samples showed up to 90% of similar digit patterns.

Table 1: Zygosity determination chart (results of identical twins)

Sl. no.	*Sample*	*General physical examination*						*Serology*	
		Sex	*Body built*	*Facial features*	*Iris*	*Hair color*	*Hair form*	*ABO*	*Rh*
1.	T1	F	Meso	Similar	Black	Black	Straight	B	+VE
	T2	F	Meso	Similar	Black	Black	Straight	B	+VE
2.	T1	M	Meso	Similar	Brown	Black	Straight	O	+VE
	T2	M	Meso	Similar	Brown	Black	Straight	O	+VE
3.	T1	M	Meso	Similar	Brown	Black	Straight	B	+VE
	T2	M	Meso	Similar	Brown	Black	Straight	B	+VE
4.	T1	M	Meso	Similar	Black	Black	Straight	B	+VE
	T2	M	Meso	Similar	Black	Black	Straight	B	+VE
5.	T1	F	Meso	Similar	Black	Black	Straight	O	+VE
	T2	F	Meso	Similar	Black	Black	Straight	O	+VE
6.	T1	M	Meso	Similar	Brown	Black	Straight	A	+VE
	T2	M	Meso	Similar	Brown	Black	Straight	A	+VE
7.	T1	M	Meso	Similar	Black	Black	Straight	B	+VE
	T2	M	Meso	Similar	Black	Black	Straight	B	+VE
8.	T1	M	Meso	Similar	Black	Black	Straight	B	+VE
	T2	M	Meso	Similar	Black	Black	Straight	B	+VE
9.	T1	M	Meso	Similar	Black	Black	Straight	A	+VE
	T2	M	Meso	Similar	Black	Black	Straight	A	+VE
10.	T1	M	Meso	Similar	Black	Black	Straight	B	+VE
	T2	M	Meso	Similar	Black	Black	Straight	B	+VE
11.	T1	M	Meso	Similar	Black	Black	Straight	A	+VE
	T2	M	Meso	Similar	Black	Black	Straight	A	+VE
12.	T1	F	Meso	Similar	Black	Black	Straight	B	+VE
	T2	F	Meso	Similar	Black	Black	Straight	B	+VE

Table 2: Zygosity determination chart (results of nonidentical twins)

Sl. no.	Sample	General physical examination						Serology	
		Sex	Body built	Facial features	Iris	Hair color	Hair form	ABO	Rh
1.	T1	F	Meso	Dissimilar	Black	Black	Curly	B	+VE
	T2	F	Meso	Dissimilar	Black	Black	Straight	B	–VE
	T1	F	Meso	Dissimilar	Black	Black	Straight	A	+VE
2.	T2	F	Meso	Dissimilar	Black	Black	Straight	O	+VE
	T1	M	Meso	Dissimilar	Black	Black	Straight	A	+VE
3.	T2	M	Meso	Dissimilar	Black	Black	Straight	B	+VE
	T1	M	Meso	Dissimilar	Black	Black	Straight	O	+VE
4.	T2	M	Meso	Dissimilar	Black	Black	Straight	O	+VE
	T1	M	Meso	Dissimilar	Black	Black	Straight	B	+VE
5.	T2	F	Meso	Dissimilar	Black	Black	Straight	AB	–VE
	T1	M	Meso	Dissimilar	Black	Black	Straight	A	+VE
6.	T2	F	Meso	Dissimilar	Black	Black	Straight	B	+VE
	T1	M	Meso	Dissimilar	Black	Black	Straight	A	+VE
7.	T2	M	Meso	Dissimilar	Black	Black	Straight	A	–VE

T1: First twin; T2: Second twin; Meso: Mesomorphic

Table 3: Sample

	DP				
	T	I	M	R	L
T1	C	A	A	L	L
	L	L	L	L	L
T2	C	A	A	L	L
	L	L	L	L	L

T1: First twin; T2: Second twin; DP: Digit pattern; T: Thumb; I: Index; M: Middle finger; R: Ring; L: Little; L: Loop, W: Whorl; A: Arch; C: Composite

Table 4: Mean intrapair differences in linear cephalometric parameters of monozygotic twin pairs

Sl. no.	Parameters	No. of Mz twin pairs	Mean Mz intrapair difference	Std. deviation
1.	TAFH	12	–0.8333	2.7906
2.	UAFH	12	–0.9167	1.9286
3.	LAFH	12	0.1667	2.1672
4.	PFH	12	0.8333	2.6571
5.	RH	12	1.0833	2.9063
6.	LI edge to A-Pog	12	0.3333	1.3026
7.	Lip to E-line	12	–0.1667	0.7177
8.	1st M to PTV	12	0.1667	2.8867
9.	FP to Pt A	12	–0.0833	1.3789
10.	1st M to ANS-PNS	12	–0.1667	2.2088
11.	UI edge to ANS-PNS	12	–0.5000	2.4308
12.	1st M to MP	12	–0.0833	1.7816
13.	LI edge to MP	12	–0.1667	1.2673
14.	MP Plane	12	–0.2500	2.3788

DISCUSSION

A twin study is a kind of genetic study done to determine heritability. The premise is that since identical twins have identical genotypes, differences between them are solely

Table 5: Mean intrapair differences in angular cephalometric parameters of monozygotic twin pairs

Sl. no	Parameters	No. of Mz twin pairs	Mean Mz intrapair difference	Std. deviation
1.	N-S-Ar	12	0.5000	2.8762
2.	S-Ar-Go	12	–0.4167	4.8328
3.	Ar-Go-Me	12	–1.0000	3.5419
4.	Ar-Go-N	12	–1.3333	1.8257
5.	N-Go-Me	12	–0.5000	3.7537
6.	I IA	12	–1.0833	5.4181
7.	LI to A-Pog	12	0.8333	3.3529
8.	N-Pog-FH	12	0.7500	2.5628
9.	OP–FH	12	–1.5000	2.5045
10.	MP-FP	12	0.5000	2.2360
11.	ANS-P NS-FH	12	–0.1667	2.3677
12.	ANS-PNS-MP	12	–0.5833	2.7784
13.	UI to ANS-PNS	12	–0.5000	5.6968
14.	N-S-GN	12	0.0833	1.1645
15.	SN-MP	12	–0.9167	2.6097
16.	UI to SN	12	1.0833	4.1000

Table 6: Mean intrapair differences in linear cephalometric parameters of dizygotic twin pairs

Sl. no	Parameters	No. of DZ twin pairs	Mean DZ intrapair difference	Std. deviation
1.	TAFH	7	0.1429	9.0999
2.	UAFH	7	0.2857	3.6839
3.	LAFH	7	–0.1429	8.3552
4.	PFH	7	0.0000	6.0827
5.	RH	7	0.0000	3.1622
6.	LI edge to A-Pog	7	1.8571	1.5735
7.	Lip to E-line	7	–0.5714	1.7182
8.	1st M to PTV	7	1.5714	3.4086
9.	FP to Pt A	7	1.8571	4.3369
10.	1st M to ANS-PNS	7	0.5714	2.5071
11.	UI edge to ANS-PNS	7	1.0000	4.3589
12.	1st M to MP	7	–3.2857	3.2513
13.	LI edge to MP	7	1.2857	4.2706
14.	MP plane	7	–3.0000	2.7080

Table 7: Mean intrapair differences in angular cephalometric parameters of dizygotic twin pairs

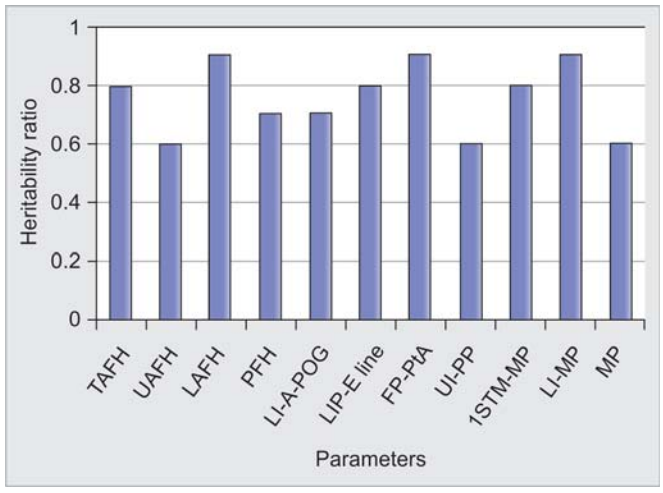
Sl. no.	*Parameters*	*No. of twin pairs*	*F-ratio*	*Level of significance*
1.	TAFH	19	9.06	<0.01*
2.	UAFH	19	2.76	>0.05
3.	LAFH	19	13.81	<0.01*
4.	PFH	19	4.43	<0.05*
5.	RH	19	0.96	>0.05
6.	LI edge to A-Pog	19	3.34	<0.05*
7.	Lip to E-line	19	5.71	<0.05*
8.	1st M to PTV	19	1.62	>0.05
9.	FP to Pt A	19	11.18	<0.01*
10.	1st M to ANS-PNS	19	1.27	>0.05
11.	UI edge to ANS-PNS	19	3.05	>0.05
12.	1st M to MP	19	6.81	<0.05*
13.	LI edge to MP	19	11.52	<0.01*
14.	MP Plane	19	2.91	>0.05

Table 8: F-ratio of linear cephalometric parameters

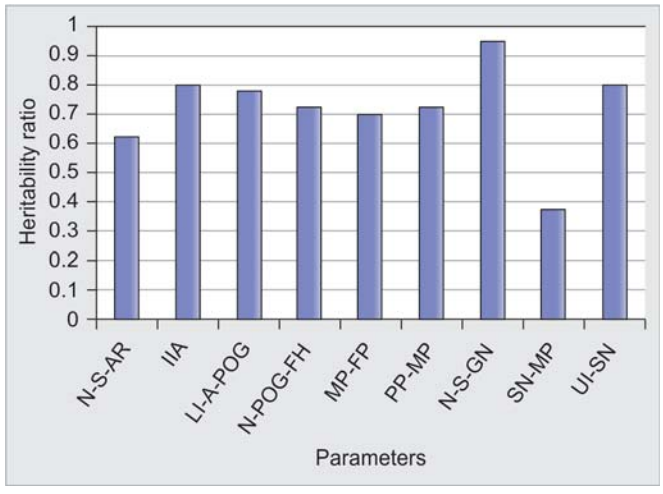
Sl. no.	*Parameters*	*No. of twin pairs*	*F-ratio*	*Level of significance*
1.	N-S-Ar	19	2.70	>0.05
2.	S-Ar-Go	19	0.75	>0.05
3.	Ar-Go-Me	19	1.99	>0.05
4.	Ar-Go-N	19	1.39	>0.05
5.	N-Go-Me	19	1.86	>0.05
6.	I IA	19	4.83	<0.05*
7.	LI to A-Pog	19	4.45	<0.05*
8.	N-Pog-FH	19	3.65	<0.05*
9.	OP-FH	19	0.59	>0.05
10.	MP-FP	19	3.40	<0.05*
11.	ANS-P NS-FH	19	1.08	>0.05
12.	ANS-PNS-MP	19	3.60	<0.05*
13.	UI to ANS-PNS	19	2.14	>0.05
14.	N-S-GN	19	17.37	<0.01*
15.	SN-MP	19	1.59	>0.05
16.	UI to SN	19	3.70	<0.05*

Table 9: F-ratio of angular cephalometric parameters

Sl. no.	*Parameters*	*No. of DZ twin pairs*	*Mean DZ intrapair difference*	*Std. deviation*
1.	N-S-Ar	7	–1.7143	4.6084
2.	S-Ar-Go	7	–0.4286	4.3149
3.	Ar-Go-Me	7	0.5714	5.3496
4.	Ar-Go-N	7	2.1429	1.5735
5.	N-Go-Me	7	–0.1429	5.3363
6.	I IA	7	–5.7143	10.9653
7.	LI to A-Pog	7	3.2857	6.6761
8.	N-Pog-FH	7	–0.5714	5.2553
9.	OP-FH	7	–0.4286	2.2990
10.	MP-FP	7	1.2857	4.1518
11.	ANS-P NS-FH	7	–0.4286	2.5071
12.	ANS-PNS-MP	7	0.4286	5.5634
13.	UI to ANS-PNS	7	5.4286	6.3733
14.	N-S-GN	7	–2.0000	4.5460
15.	SN-MP	7	–0.7143	3.5456
16.	UI to SN	7	4.5714	6.8764



Graph 1: Heritability of significant linear cephalometric parameters



Graph 2: Heritability of significant angular cephalometric parameters

due to environmental factors. By examining the degree to which twins are differentiated, a study may determine the extent to which a particular trait is influenced by genes or the environment.[9,10]

'Twins have a special claim upon our attention; it is that their history affords means of distinguishing between the effects of tendencies received at birth, and those that were imposed by the special circumstances of their after lives.'[11,12]

It has been thoroughly documented that measurements of the craniofacial complexes have moderate to high heritability that they are primarily a consequence of 'nature' rather than 'nurture'.

Clinical perceptions favor the idea that heredity plays a major role in both craniofacial structure and tooth-based malocclusions.

A more thorough knowledge of the degree of heritability of craniofacial structures could open new perspectives in orthodontics. However, inheritance of cephalometric parameters is only little understood (Tables 10 and 11).[1]

Many polygenic craniofacial traits are susceptible to environmental modification and can be difficult to study

with conventional methods. Twin studies provide an opportunity to analyze such traits.[13,14]

The aim of the present investigation was to explore the genetic and environmental influences on craniofacial dimensions in a group of subjects using the twin study method.[15,16]

In the present study, 19 pairs of twins were selected with ages ranging from 14 to 25 years. Sex was not taken into consideration. After necessary investigations they were divided into 12 pairs of monozygotic and seven pairs of dizygotic twins. Thirty parameters on the lateral cephalogram that are relevant to clinical orthodontic practice were taken and measured. The mean intrapair variance were calculated to each parameter in both monozygotic and dizygotic twins and F-ratio, heritability value (H), variance of heritability V (H), standard error SE (H) were calculated.

The linear variables which showed statistically significant values are:

1. Total anterior facial height is significant at 1% level
2. Upper anterior facial height is significant at 5% level
3. Lower anterior facial height is significant at 1% level
4. Posterior facial height is significant at 5% level
5. Lower incisal edge to A-Pog is significant at 1% level
6. Lip to E-line is significant at 1% level
7. Facial plane to point A is significant at 1% level
8. Upper 1st incisal edge to ANS-PNS is significant at 5% level
9. Lower 1st molar mesial cusp tip to mandibular plane is significant at 1% level
10. Lower 1st incisal edge to mandibular plane is significant at 1% level
11. Mandibular plane is significant at 5% level.

Parameters significant at 5% level indicate significant genetic influence.

Parameters significant at 1% level indicate highly significant genetic influence.

The remaining linear variables did not show any statistical significance as can be observed from table.

The angular variables showing statistically significant values are:

Table 10: Heritability significant of linear cephalometric parameters (Graph 1)

Sl. no.	*Parameters*	*No. of twin pairs*	*H*	*SE (H)*	*Level of significance*
1.	TAFH	19	0.8897	0.2209	<0.01*
2.	UAFH	19	0.6372	0.7266	<0.05*
3.	LAFH	19	0.9276	0.1450	<0.01*
4.	PFH	19	0.7740	0.4525	<0.05*
5.	RH	19	–0.0403	2.0833	>0.05
6.	LI edge to A-Pog	19	0.7009	0.5991	<0.05*
7.	Lip to E-line	19	0.8250	0.3505	<0.01*
8.	1st M to PTV	19	0.3831	1.2353	>0.05
9.	FP to Pt A	19	0.9106	0.1791	<0.01*
10.	1st M to ANS-PNS	19	0.2125	1.5770	>0.05
11.	UI edge to ANS-PNS	19	0.6722	0.6565	<0.05*
12.	1st M to MP	19	0.8531	0.2941	<0.01*
13.	LI edge to MP	19	0.9132	0.1738	<0.01*
14.	MP Plane	19	0.6565	0.6878	<0.05*

*Means differed significance

Table 11: Heritability significant of angular cephalometric parameters (Graph 2)

S. no.	*Parameters*	*No. of twin pairs*	*H*	*SE (H)*	*Level of significance*
1.	N-S-Ar	19	0.6295	0.7420	<0.05*
2.	S-Ar-Go	19	–0.3370	2.6775	>0.05
3.	Ar-Go-Me	19	0.4971	1.0071	>0.05
4.	Ar-Go-N	19	0.2801	1.4416	>0.05
5.	N-Go-Me	19	0.4610	1.0794	>0.05
6.	I IA	19	0.7931	0.4144	<0.05*
7.	LI to A-Pog	19	0.7755	0.4496	<0.05*
8.	N-Pog-FH	19	0.7257	0.5493	<0.05*
9.	OP-FH	19	–0.6970	3.3984	>0.05
10.	MP-FP	19	0.7058	0.5892	<0.05*
11.	ANS-PNS-FH	19	0.0726	1.8571	>0.05
12.	ANS-PNS-MP	19	0.7224	0.5560	<0.05*
13.	UI to ANS-PNS	19	0.5333	0.9345	>0.05
14.	N-S-GN	19	0.9424	0.1153	<0.01*
15.	SN-MP	19	0.3724	1.2569	<0.05*
16.	UI to SN	19	0.7901	0.5406	<0.05*

*Means differed significance

1. Saddle angle is significant at 5% level
2. Interincisal angle is significant at 5% level
3. Lower incisor to A-Pog angle is significant at 5% level
4. FH-N-pog angle is significant at 5% level
5. Mandibular plane to facial plane angle is significant at 5% level
6. ANS-PNS to mandibular plane angle is significant at 5% level
7. N-S-GN is significant at 1% level
8. Upper incisor to S-N angle is significant at 5% level.

The remaining angular variables did not show any statistical significance as can be observed from table.

Parameters significant at 5% level indicate significant genetic influence.

Parameters significant at 1% level indicate highly significant genetic influence.

CONCLUSION

The results of the present research support the hypothesis that many of 30 cephalometric variables evaluated were under strong genetic control. A significant heritability values were obtained for 20 out of 30 parameters studied.

Out of the 30 parameters, 20 showed significant genetic heritability. Among the later seven had highly significant heritability, those are total anterior facial height, lower anterior facial height, lip to E line, facial plane to point A, mandibular 1st molar to mandibular plane, lower incisal edge to mandibular plane and Y-axis angle.

Among these 20 readings 11 were linear (8 vertical and 3 anteroposterior) and nine were angular.

Thus the twin study carried out here clearly indicates that craniofacial matrix is under substantial genetic control and the redirection of a basic growth pattern may be modified only within biological limits which are harmonious for the patient.

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