The Hereditary Components of Mandibular Growth, A Longitudinal Twin Study

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INTRODUCTION

The treatment of facial skeletal anomalies confronts the orthodontist with a special challenge: improving the facial balance while correcting the malocclusion. This is dependent on the amount of growth of the jaws. Therefore, the treatment of skeletal deviations of the jaw can be facilitated if facial growth can be predicted.

Facial growth is controlled by the inherent genetic make-up and the environmental influences upon an individual. Morphologic characteristics of the craniofacial complex are believed to be polygenic in nature and identification of the specific genes or gene groups which control facial morphology has not yet been accomplished. On the side of environmental influences, investigation of treatment effects has revealed that the facioskeletal growth pattern can be modified by means of orthopedic and orthodontic forces.[13,14,18,29,30]

It has been established that there is a considerable individual variability in the amount, timing, and velocity of facial growth;[2,10,17,23] and that sex,[32] facial type,[26] and heredity[15,16,21,39] are factors that influence individual variability of growth.

The purpose of this study is to investigate the hereditary and environmental factors influencing mandibular growth. The method of investigation is by means of monozygotic, as compared with dizygotic, twins over a ten-year period.

The clinical importance of this study is that, if genetic determination is strong for the size, shape, and position of the mandible, then the influence of orthopedic forces may be only minimal. This information will be of paramount importance in the design of an orthodontic treatment plan and its prognosis.

REVIEW OF THE LITERATURE

Studies by Nanda,[23] Björk,[3,4,5] Bambha[2] and Sahni[27] have demonstrated changes in the growth pattern of the individual. A general circumpubertal spurt of growth has been identified. The times of onset and peak of facial growth have been found different for the various dimensions. Since the relative rate of growth was not the same, the form of the face changed. Among the causes of the variability in amount, timing, and velocity of facial growth are sex, age, facial type, environment and heredity.

Heredity has been investigated by racial, family-line, and twin methods. Racial studies by Cotton, Takano and Wong[9] and by Sassouni[29] showed definite differences in size and position of certain facial structures among the races investigated. Parent-offspring similarities in facial structures also have been shown by Wylie,[40] Sassouni,[30] Brown,[7] Seitz,[34] and Porado.[25] Avery,[1] in a family-line study of growth and heredity, found that some facial dimensions show increasing and others, decreasing, similarity with age.

Galton[12] was the first to discuss the merits of twin investigations. Compari-

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sons of the between-twin pair differences yielded relative assessments of the influence of heredity and environment if the twin pairs were raised in relatively identical environments. There are two types of twins, monozygotic and dizygotic. The determination of zygosity is critical. Many investigators, including Lundstrom,[21] Bonello,[6] and Meisel[22] determined zygosity subjectively. These studies, therefore, are of questionable scientific basis. Siemanns,[35] Rife,[26] Sutton et al.,[36] and Osborne and DeGeorge[24] utilized blood-typing as a method to determine zygosity. Rife,[26] Clark,[8] and Townsend[37] utilized fingerprint traits. Lundstrom,[21] Wise,[38] and Kraus[19] determined zygosity by comparing the morphology of the teeth. Faulkner[11] stated that tests of the placenta for vascularity, number of choria, and dry weight can help to determine the differences due to maternal prenatal environment, or genetic differences. Other traits such as hair, eye and skin color, freckles, acne, furrowing of the tongue, form of the face, ears, nails, and body build have been used to determine zygosity.[35]

There is practically no study of longitudinal facial growth of twins. Wuslich[39] studied craniofacial growth and development on a longitudinal basis in seventeen of the thirty-nine like-sexed twins used by Bonello.[6] He used cephalometric radiographs, dental models, physioprint photographs, and blood samples in order to determine zygosity, to select the best cephalometric measurements, and to formulate a hereditary analysis based on monozygotic versus dizygotic twin-groups. In addition, he utilized dermatoglyphics and tooth morphology to ascertain zygosity. On the basis of the zygosity analysis, all the twins were divided into groups, monozygotic or dizygotic. Wuslich found that only the position of the maxilla indicated that it was under less environmental influence. The sample was incomplete as there were only five dizygotic twin pairs as compared with twelve monozygotic pairs. The group comparisons were, therefore, not ideal.

The identification of hereditary and environmental influences of mandibular growth still remains to be done. The present study is an attempt in this direction.

Experimental Design

Twins whose zygosity had been objectively determined according to serology, dermatoglyphics, tooth morphology, and physioprints were selected. Of twenty-two pairs, twelve were monozygotic (10 female and 2 male) and ten were dizygotic (7 male and 3 female). All twins were first seen from 4 to 13 years of age during their growth period (Fig. 1).

The dependent variable, facial dimension, was recorded by oriented lateral radiographic cephalometry. The Broadbent-Bolton cephalometer was used. The standard five-foot distance between the target and the midsagittal plane of the patient was used. From this plane to the film was a constant distance of six inches. The head was held with the Frankfort horizontal plane parallel to the floor. Magnification was constant for all films (6%). The x-rays were taken on two occasions, 1955-1958 and 1965-1967. Identification of anatomic structures and landmarks was based on the description in Krogman and Sassouni's *A Syllabus in Roentgenographic Cephalometry.*[20]

During the tracing of the lateral cephalograms the midline of all contours of bilateral structures was traced to minimize the error due to positioning, differential magnification, and asymmetry.

Method of Measurement

Fifteen skeletal measurements were taken. Figure 2 illustrates the skeleto-

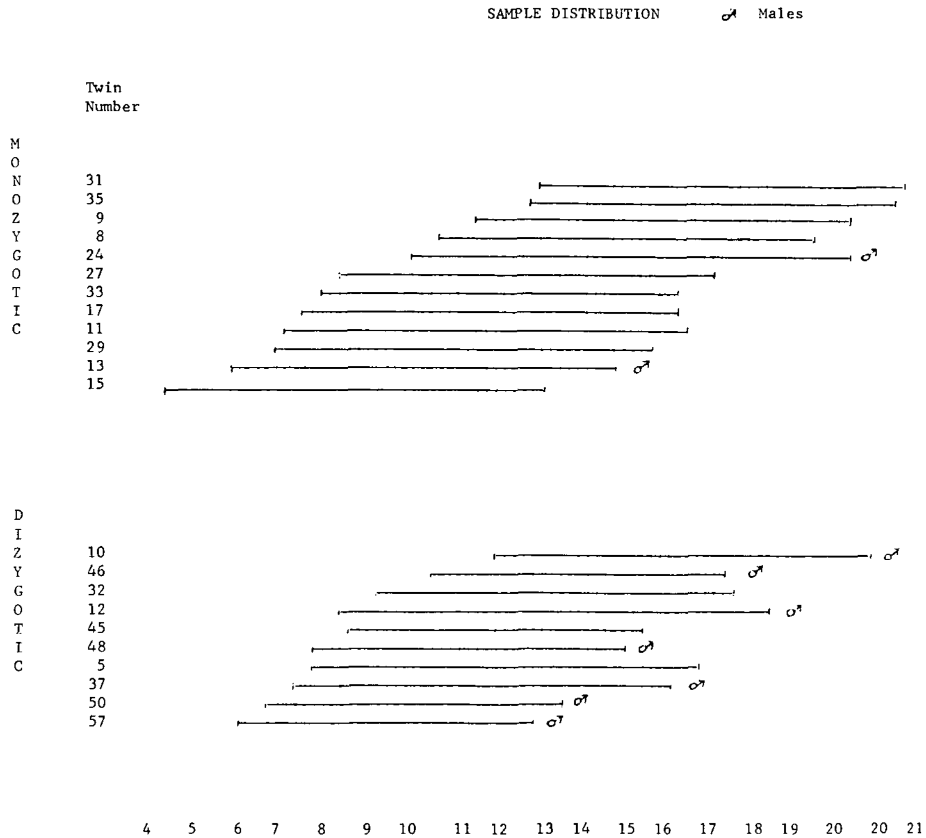

Fig. 1 Study sample

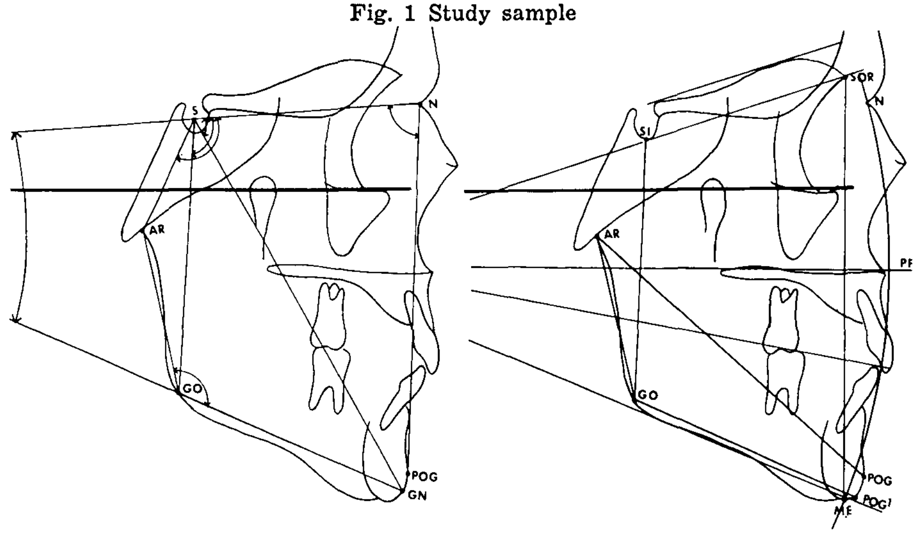

Fig. 2 Positional: SN-GoGn, N-S-Go, S-N-Pog, N-S-Gn, Ar-S-N, Ar-Go-Gn; Archial: ANS-AA, Pog-AA; Dimensional: Ar-Pog, Ar-Go, Go-Pog; Facial height: SOR-Me (TA), SOR-PP (UA), PP-Me (LA), Si-Go (TP); Vertical index: $\frac{TP+UA}{TA \quad LA}$

PP - palatal plane, SOR - supraorbitale, Si - lowest border of sella turcica.

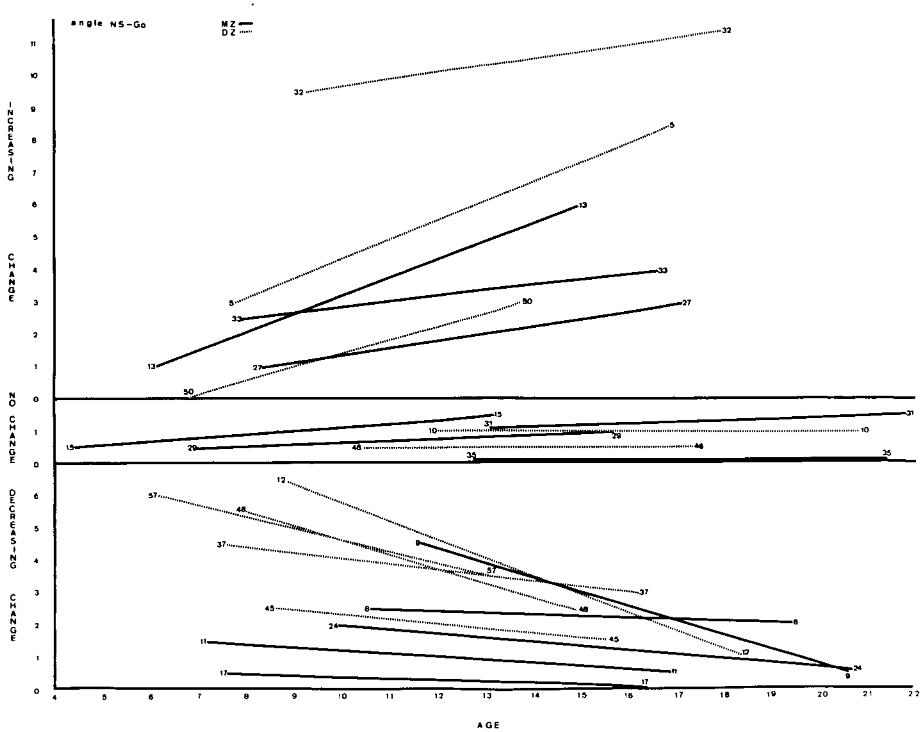

Fig. 3

facial measurements utilized in the study. Reliability of measurements was tested using the intrajudge and interjudge test and evaluated as a percentage error.

Findings

The data were analyzed to find the monozygotic variance, the dizygotic variance, and the between-group variance (MZ versus DZ). The between-group variance was assessed by the F-ratio to evaluate the relative environmental influence on the facial dimensions during growth.

The four of the fifteen original measurements that were selected as being under strong hereditary or weak environmental influence during growth were N-S-Go, N-S-Gn, lower anterior facial height, and total anterior facial height. These were contrasted graphically with two nonsignificant measurements (S-N-Pog and Ar-Pog) to show individual absolute changes of each twin during growth and within-twin pair absolute difference during growth.

The graphic representation consisted of 1) absolute growth changes between monozygotic and dizygotic pairs and 2) absolute individual growth changes. Age, in years, was plotted on the abscissa and three categories of no-change, increasing change, and decreasing change were plotted on the ordinate scale in degrees. Figure 3 and Table I summarize the findings for one measurement (N-S-Go).

It can be seen that nearly the same number of monozygotic and dizygotic

TABLE I

Changes for N-S-Go Between Monozygotic and Dizygotic Twins

Change over 10 yrs.	MZ	DZ
Increasing differences	3	3
No Change	4	2
Decreasing differences	5	5

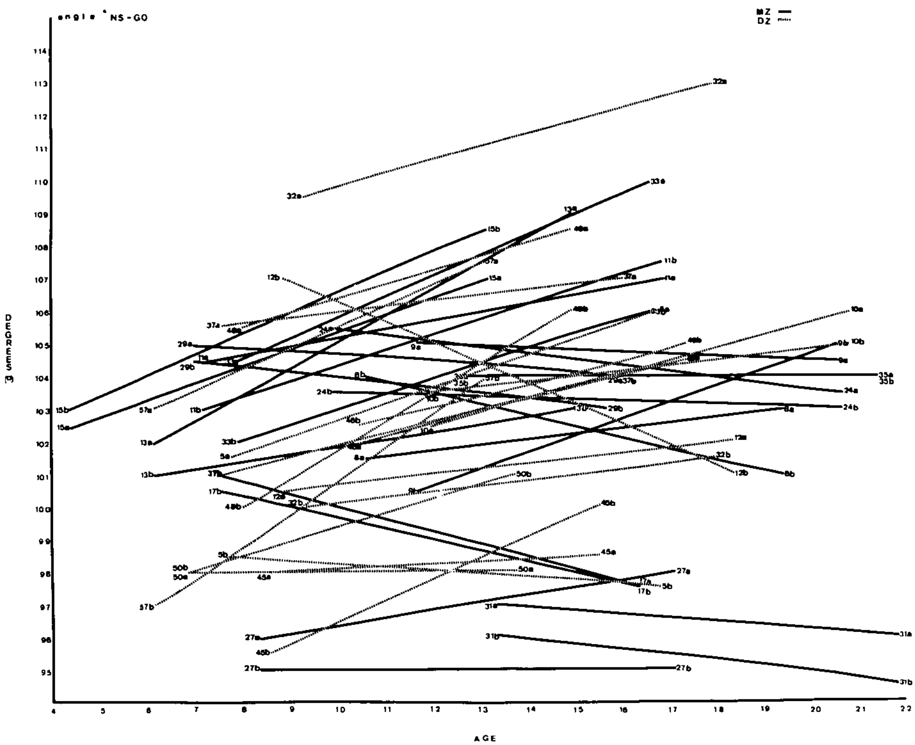

Fig. 4

twins grow with increasing and decreasing differences occurring, while more monozygotic than dizygotic twins grow with no change in similarity.

Figure 4 illustrates the procedure for the measurement N-S-Go for the individual twins. A large amount of variability appears to be present. Angular growth is difficult to assess since any one or all three of the landmarks forming the angle can and/or do change. No apparent real differences in growth of MZ or DZ twins were observed.

The same procedure was followed for the three other significant dimensions: N-S-Gn, total anterior facial height, and lower anterior facial height, and the two nonsignificant dimensions (S-N-Pog and Ar-Pog).

For the N-S-Gn angle the findings were similar to N-S-Go. As previously mentioned, a nonsignificant angular measurement (S-N-Pog) was graphically presented and the findings for this measurement agreed with what was found for the two significant measurements.

For the lower anterior facial height and total anterior facial height nearly the same number of MZ and DZ twins grew with increasing and decreasing differences as well as with no change in differences. However, the number of twins in each category was not well distributed as with previous dimensions. The rule of variability seen in the other studied dimensions held true here. No real differences existed between growth of MZ and DZ twins for these dimensions.

The findings for Ar-Pog (statistically nonsignificant) established that approximately the same number of monozygotic and dizygotic twins grew increasingly divergent. More monozygotic than dizygotic twins did not change during

TABLE II
Comparison with Literature
F-Ratios
Measurements

Author	TAFH	UAFH	LAFH	Corpus Length	Total Mand. Length	Ramus Length	SN-GoGn	S-N-Pog	Gonial Length
Lundstrom							3.08*	3.97*	2.24*
Horowitz	5.01*	1.18*	5.92*	4.75*					
Hunter	6.05*	2.51*	4.44*	4.58*	2.21*	4.30*			
This Study (Early)	6.41*	5.62*	4.71*	4.26*	1.49	2.63	2.71	1.90	1.99
This Study (Late)	5.17*	2.55	3.92*	0.80	1.81	0.87	2.80	1.65	2.39

* Significant at 5% level

growth. A larger percentage of DZ twins than MZ grew more similar. The same variability in general growth found for the other dimensions was also apparent. No growth differences were noticed between monozygotic and dizygotic twins.

Discussion

Fifteen measurements of the lateral facial skeleton were taken, handled cross-sectionally and longitudinally, statistically, as well as graphically. The following dimensions are highly affected by the environment: SN-GoGn, S-N-Pog, Ar-Go-Gn, ANS-AA, Ar-Pog, Ar-Go, TPFH, $\frac{TPFH}{TAFH}$, $\frac{TPFH + UAFH}{TAFH \quad LAFH}$. Eight measurements were significant only at an early age: $\frac{UAFH}{LAFH}$, N-S-Gn, Go-Pog, LAFH, Ar-S-N, UAFH, TAFH, N-S-Go. Five were significant only at a late age: LAFH, N-S-Go, Pog-AA, N-S-Gn, TAFH. Only four measurements were significant during growth at both early and late ages: N-S-Go, N-S-Gn, LAFH, and TAFH.

It can thus be said that these four dimensions, found to be less affected by environment during facial growth, would then be less influenced by an orthodontic force which, in reality, is an environmental intervention. In other words, although all facial dimensions are under hereditary influence, those which were statistically significant at both an early and a late age during growth are more influenced by heredity than the others. It would then follow that, since three out of the four measurements are reflections of vertical dimensions, vertical problems during growth would cause more concern in treatment as well as in retention. Conversely, anteroposterior problems should be treated with less difficulty and with less tendency to relapse.

The statistical results of this study have been compared cross-sectionally with previous twin studies (Table II). The results of the comparison of the F-ratio in previous twin studies show a general consistency.

TAFH - Total Anterior Face Height

All investigators showed this dimension to be significant and under minimal environmental influence.

UAFH - Upper Anterior Face Height

Considering that the sample by Horowitz contained only adults and the present study at the later age contained primarily adults, the results are the same. Hunter had a sample of individuals who were growing as did the present study at the earlier age. It would seem that during growth the upper anterior facial height is under

TABLE III
Comparison of Twin Samples

Author	Number M	F	Total MZ	M	F	Total DZ	Age Range yrs.	Mean yrs.	SD yrs.
Ludstrom	15	35	50	26	24	50	10-19	13.4	2.2
Horowitz	—	—	35	—	—	21	18-55	—	—
Hunter	21	16	37	13	22	35	11.8-21	16.4	1.7
This Study (Early)	2	10	12	7	3	10	4.4-13.2	8.7	2.2
This Study (Late)	2	10	12	7	3	10	13.1-21.8	17.2	2.6

minimal environmental influence, but once total growth has been completed, upper anterior face height seems to have been under strong environmental influence. This may be due to sudden late growth changes in the nasal and perinasal area.

LAFH - Lower Anterior Face Height

All investigators showed this dimension to be significant and under minimal environmental influence.

Corpus Length

All investigators showed this dimension to be significant and under minimal environmental influence except at the later age. This could be due to the fact that the sample of the present study was not well-distributed as to sex.

Total Mandibular Length and Ramus Length

The findings of this study were not statistically significant as was the study by Hunter. The inconsistency of the findings can be attributed to the differences in the sample size and sex distribution.

Differences in the samples are apparent at every level of comparison as is evident in Table III. This could explain some of the differences between the results. However, in spite of the sample differences there are definite areas of statistical agreement.

The graphic representation of between-twin differences in growth and the within-and between-twin absolute dimensional and angular changes have shown the expected traits of growth. Linear growth is more easily explained than angular changes. The measurement between two points during growth rarely becomes smaller unless there is measurement error. LAFH and TAFH graphically increased. Examination of the graphs showed little difference between the monozygotic and dizygotic twin groups. Some twins in both groups grew with no change in similarity, whereas others became more or less different.

Angular change is more difficult to interpret because there are three areas of possible change which can affect an angular measurement. It is possible for the angular measurement of certain points to increase or decrease during growth. For instance, in measuring the angles N-S-Go and N-S-Gn all three of the individual anatomic areas which compose the angle can change during growth. Nasion can grow upward and forward, or downward and forward. Sella turcica can grow downward and backward during growth. The accepted growth pattern of gonion is usually downward and forward, but when more vertical than horizontal growth occurs, the pattern changes to downward and backward. Gnathion usually grows downward and forward, but this pattern changes to downward and backward when more vertical than horizontal growth occurs also. Therefore, during growth the angles N-S-Go and N-S-Gn showed increases as well as decreases.

Twin growth comparisons have not shown between-twin change, increasing change, or decreasing change during growth.

The present study is the first reported study of twin growth although with a limited sample. This study also yielded the variability of twin growth in an untreated sample. The four measurements selected can now be used to determine treatment-versus-growth in a future twin study, where one twin is held as control and another has orthodontic treatment. This could answer the question: What portion of orthodontic treatment is attributed to growth, and what definite effect does treatment have upon facial growth?

Summary

Growth prediction of individual facial bones and complexes is presently inadequate. By using the twin method a study was undertaken to determine whether there were increasing or decreasing similarities during growth. The initial hypothesis was: During facial growth is there an increasing influence of the environment upon facial dimensions?

Twins whose zygosity had been objectively determined were selected. Twelve twin pairs were monozygotic and ten were dizygotic.

Fifteen measurements were selected. The criteria of selection were: skeletal measurements which were used previously in studies of growth, variation, and heredity, and which were comparable from one author to another. The measurements included horizontal and vertical dimensions and measured position by angular as well as proportional (archial) means, linear distances (dimensional) and included proportions.

Reliability of measurements was tested using the intrajudge test and the interjudge test and calculated as a percentage error. The intrajudge error ranged between 0.2 to 5.0 per cent error. The interjudge error ranged between 0.5 and 42.0 per cent error. The latter error contained not only measurement error but also tracing and landmark identification error. The result of the investigation would have changed greatly if the second investigator's measurements had been used. Error is extremely critical in a twin study.

The data were analyzed to find the MZ variance, the DZ variance, and the between-group variance. The between-group variance was assessed by the F-ratio to evaluate the relative environmental influences on the facial dimensions during growth.

Only four of the fifteen original measurements were selected as being under strong hereditary or weak environmental influence during growth. They were N-S-Go, N-S-Gn, lower anterior facial height, and total anterior facial height.

Graphically, these four finally-selected measurements were contrasted with two nonsignificant measurements (S-N-Pog and Ar-Pog) to show individual absolute changes of each twin during growth and within-twin pair absolute differences during growth. Graphic comparisons showed little if any difference between the significant and insignificant measurements. Growth was variable in both MZ and DZ twins. Males grew more and longer than females.

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