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Craniofacial Morphology and Occlusal Variation in Monozygous and Dizygous Twins

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A study of 60 pairs of twins, 30 monozygous and 30 dizygous, finding a strong genetic component overlaid by functional adaptation most prominent in the dental area.

KEY WORDS: • Environmental influences • Genetics • Heredity • • Occlusion • Twins •

Orthodontists are charged with the task of altering dental and skeletal morphology in growing and non-growing individuals at a one-on-one clinical level.

These alterations must be carried out in a population characterized by great biologic diversity, and with considerable dentoskeletal variability, as evidenced by the vast array of differently-shaped faces and occlusal relationships. This variability of the craniofacial skeleton and dentition has been attributed to both genetic and environmental influences (Hughes and Moore 1941, Lundström 1954, Nakata et al. 1973).

For the orthodontist, the focus must be on the relationship of craniofacial variation to the ultimate occlusal relationship.

One approach to refining our knowledge of the relative contribution of genetic and environmental influences on the variability of the craniofacial skeleton and dentition has been through the comparative study of monozygous and dizygous twins. Monozygous twin pairs have identical genotypes, while the dizygous twin pairs have different genotypes. Hence, use of this model has proven effective in partitioning the variance of the craniofacial skeleton and its appended dentition into genetic and environmental components (Wylie 1944, Lunström 1954, Hunter 1965, Watnik 1969, Nakata et al. 1973).

The purpose of the present investigation is to study the variation within the craniofacial skeletons of monozygous and dizygous twins in terms of shape and spatial arrangement of the component parts, and to relate this variation to the occlusion of the teeth.

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— Materials and Methods —

The sample for this study consisted of 30 pairs of monozygous twins and 30 pairs of like-sexed dizygous twins. These twin pairs were representative of a heterogeneous mixture of multiple ethnic groups in Southeastern Michigan.

Zygosity for this sample was determined by utilizing serological techniques, iris pattern, fingerprints, carpal films, and hair color. Dental casts of all monozygous twins were also examined to confirm that buccal interdigitation and the morphology of mandibular bicuspids were identical.

The twin sets in the monozygous group consisted of 12 female pairs and 18 male pairs, with ages ranging from 12.0 years to 18.8 years (mean age 15.9 years). The twin sets in the dizygous group consisted of 18 female pairs and 12 male pairs with ages between 12.4 years and 21.0 years (mean age 15.5 years.

This study assessed the craniofacial complex both qualitatively and quanitatively, utilizing digitized tracings of lateral cephalographs and computer-generated plots made from these digitized tracings (Walker and Kowalski 1971).

Qualitative Methods

A visual comparison was made by direct superimposition of the computer- generated plots derived from the digitized tracings of lateral cephalographs from each twin set in the study. The shape and spatial arrangement of the component parts of the craniofacial skeleton (cranium, cranial base, maxilla, and mandible) were compared.

Shape

The shape of the cranium, cranial base, maxilla, and mandible were evaluated separated for each twin pair. These osseous regions were assessed subjectively by a *best fit* method with reference to overall shape (Brodie 1944).

In order to factor out the variation in shape of the mandible and cranial base resulting from angular differences between component regions, these structures were evaluated separately in terms of their component regions. Hence, the mandible was evaluated in terms of the shape of the ramus, corpus, gonial angle, and symphysis. The cranial base was evaluated in terms of the anterior cranial base and posterior cranial base.

Each twin pair was assigned to one of the following categories for each region of the craniofacial complex; *similar, dissimilar,* and *similar except for angulation,* based on this qualitative assessment of shape. The *similar except for angulation* group was ultimately included with the *similar* category for analysis.

Spatial Arrangement

The relative positions of the craniofacial components were subjectively assessed by superimposition of the computer generated plots in two different areas of the craniofacial complex.

Sella-nasion plane and the anatomic occlusal plane were utilized as planes of reference for superimposition. Sella-nasion was utilized with registration at sella, and the anatomic occlusal plane was utilized with registration at the incisal edge of the lower incisors (Figs. 1 and 2).

The spatial arrangement of each craniofacial component relative to both of the planes of superimposition was assessed for each twin pair as either similar or dissimilar. A total of 120 assessments for each plane of superimposition were made for each twin group (4 bones × 30 pairs per group).

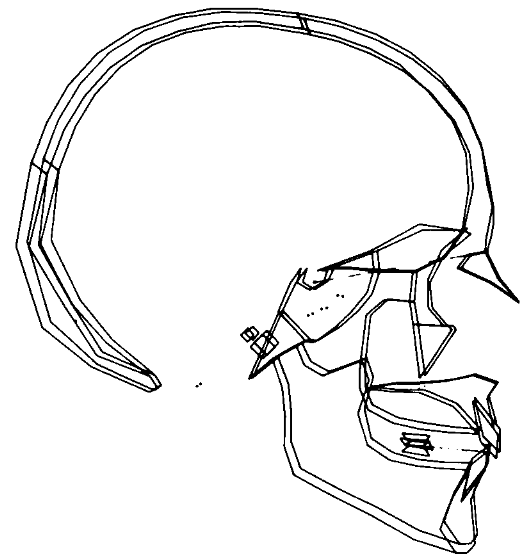


Fig. 1 Superimposition of computer-generated plots oriented on sella-nasion plane registered at sella.

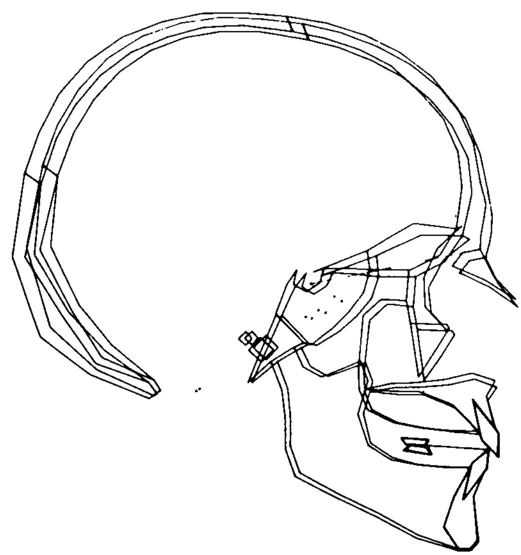


Fig. 2 Superimposition of computer-generated plots on anatomic occlusal plane registered at the lower incisor edge.

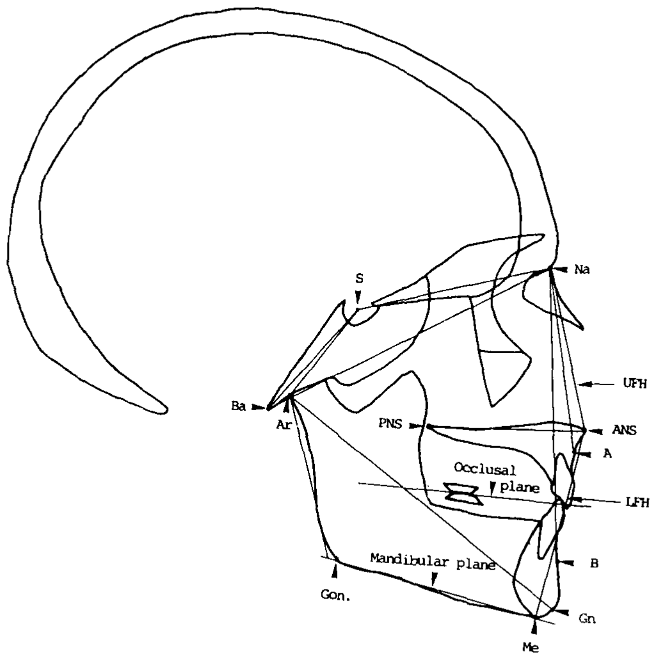


Fig. 3 Computer-generated plot with linear and angular variables utilized in this study.

Quantitative Methods

From the digitized tracings of the lateral cephalographs, twelve linear and angular variables were generated for each twin (Fig. 3).

Linear Ratios

ANS-PNS : Ba-N
Ar-Gn : Ba-N
ANS-PNS : Ar-Gn
UFH : LFH

Spatial Arrangement (angles)

S-N-A
S-N-B
Ar-S-N
Ba-S-N
Gonial angle
Occlusal plane / Mandibular plane angle
Occlusal plane / Palatal plane angle
Mandibular plane / palatal plane angle

These variables allowed quantification of relative size and spatial arrangement of the component parts of the craniofacial complex.

Size differences between the twins making up each pair was factored out by using a series of ratios to indicate the overall proportionality in size of the component parts rather that absolute size measurements.

This data was used to statistically assess intrapair and interpair variation for both twin groups.

Statistical Analysis

Qualitative Evaluations

The assigned catagories were tabulated and the independence of the four craniofacial components was evaluated utilizing Fischer's exact test for association in 2×2 contingency tables *(Chi Square).*

The relationship between the monozygous and dizygous twin groups was also assessed using Fischer's exact test.

Quantitative Evaluations

Descriptive statistics including minimum, maximum, mean, and standard deviation were used to develop statistical information for the twelve variables.

Intrapair correlation coeffecient matrices for both the monozygous and dizygous twin groups are compared.

Student t tests were applied to determine the significant intrapair mean differences between variables of the monozygous and dizygous twin groups.

A coeffecient of heritability was also determined for each variable to indicate the relative genetic influence on each of the variables studied (Hunter 1965, Nakata et al. 1973).

— Results —

Qualitative

Shape

Overall evaluation of shape for this sample involved 120 individual assessments for each of the monozygous and dizygous groups (4 bones × 30 twin pairs). This resulted in 92% *similar* assessments for the bones of the monozygous group and 71% *similar* assessments assigned to the dizygous group (Table 1).

Within the monozygous twin pairs, similar shape was found for the cranium in 80%, cranial base in 63%, maxilla in 87%, and mandible in 60% (Graph 1).

If the differences in shape of the components of the craniofacial complex which were attributable to angulation differences in the component regions of the bone were factored out, the degree of similarity in shape changed (Table 2).

Within the monozygous twin pairs, the shapes of the cranial base and mandible were similar in 100% of the cases when the angulation of the cranial base, corpus/ramus, and symphysis were taken into consideration. The shape of the maxilla and cranium are not influenced by angulation differences, so the degree of similarity did not differ for these structures.

Within the dizygous twin pairs, similar shape was found for the cranium in 73%, for the cranial base in 23%, maxilla in 83%, and mandible in 23% (Graph 1).

When angulation of the component areas of these structures was also considered, the shape of the cranial base was similar in only 57%, and the shape of the mandible similar in 70% of the cases. As

	Similar +	Similar Except Angulation*	= Total Similar	Percent Similar	Dissimilar	Fishers's ** Exact Test
Monozygous	87	23	110	92	10	0.00002
Dizygous	61	24	85	71	35	0.00002

*Differences limited to flexure of the cranial angle, gonial angulation, and/or symphyseal angulation.

**Significant at or below the 0.05 level

Table 1
Overall evaluation of shape of the components of the craniofacial complex for the monozygous and dizygous twin groups.

with the monozygous twins, angulation differences did influence the degree of similarity of these structures within the dizygous twin pairs (Graph 2).

Spatial Arrangement

The evaluation of differences in spatial arrangement of the craniofacial components as compared by superimposition on the sella-nasion plane and on the anatomic occlusal plane revealed important differences in the apparent spatial arrangement of these structures (Figs. 4-7).

Superimposition on the sella-nasion plane, registered at Sella, revealed a decreasing degree of similarity of the spatial arrangement of the craniofacial complex as the distance from the plane of superimposition increased (Graph 3).

The monozygous twin pairs exhibited a total of 44% similar assigned catagories for the position of the craniofacial components as related to the sella-nasion plane, while the dizygous twin pairs exhibited a total of 38% similar categories (Table 3).

Superimposition on the anatomic occlusal plane registered at the lower incisor also revealed a decreasing degree of similarity for the spatial arrangement of the craniofacial complex as the distance from the plane of superimposition increased. However, it was not as marked or as uniform as when superimposition on the sella-nasion plane was considered (Graph 4).

The monozygous twin pairs exhibited a total of 59% similar catagories assigned to the position of craniofacial components, while the dizygous twins exhibited a total of 30% similar catagories assigned to the position of the craniofacial components (Table 4).

— Discussion —

Variability observed in the craniofacial skeleton must undoubtedly have some effect on the occlusal articulation of the teeth as the denture-bearing areas are contained in the various skeletal elements making up the craniofacial complex.

This study shows that both the monozygous and dizygous twin pairs revealed intra-pair variation in terms of relative size, shape, and spatial arrangement of the bony components of the craniofacial skeleton. However, the absolute differences and variance were observed to be considerably greater within the dizygous twin pairs than in the monozygous twin pairs (Tables 5 and 6).

	Monozygous		Dizygous		Fisher's**
	Similar	Dissimilar	Similar	Dissimilar	Exact Test
Cranium	24	6	22	8	0.38
Cranial Base	30 (19/11)*	0	17 (7/10)	13	0.00002
Maxilla	26	4	25	5	0.50
Mandible	30(18/12)	0	21(7/14)	9	0.009

* Similar/similar except angulation
**Significant at or below the 0.05 level

Table 2
Shape of Individual Craniofacial components as determined by best fit method.

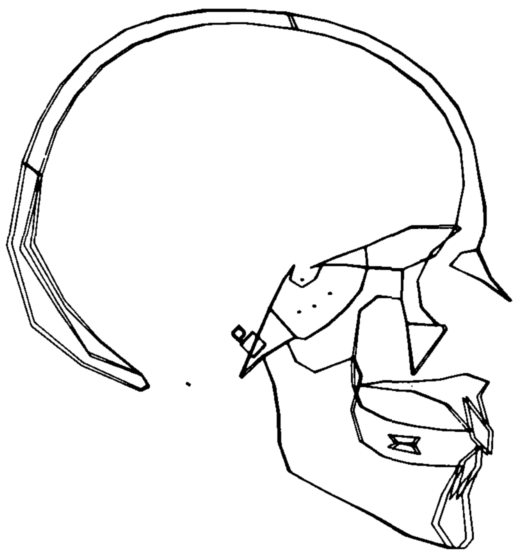


Fig. 4 Computer-generated mean patterns representing the monozygous twin pairs superimposed on sella-nasion plane registered at sella.

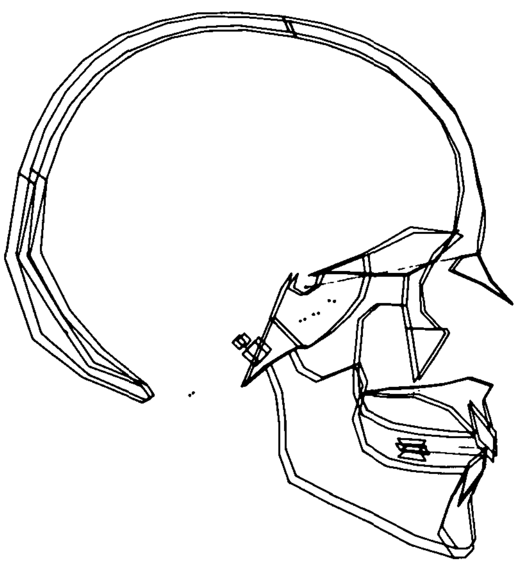


Fig. 5 Mean computer plots representing the dizygous twin pairs superimposed on sella-nasion plane registered at sella.

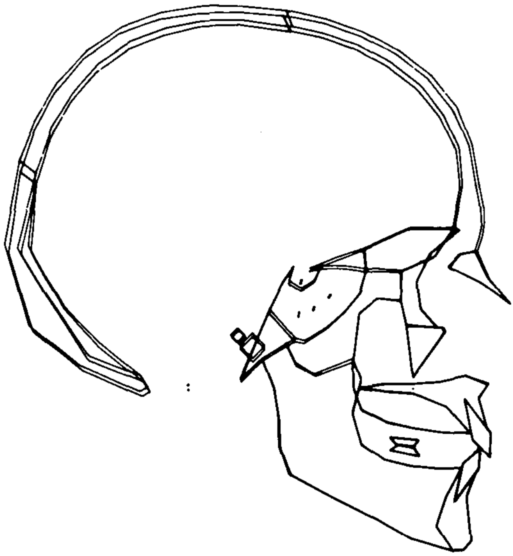


Fig. 6 Mean computer plots representing the monozygous twin pairs superimposed on the anatomic occlusal plane registered at the lower incisal edge.

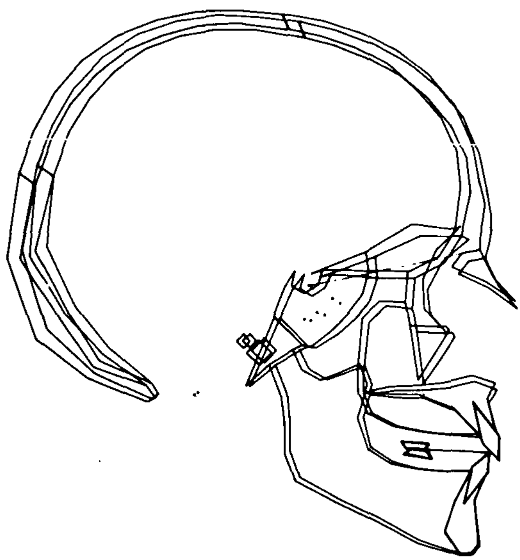
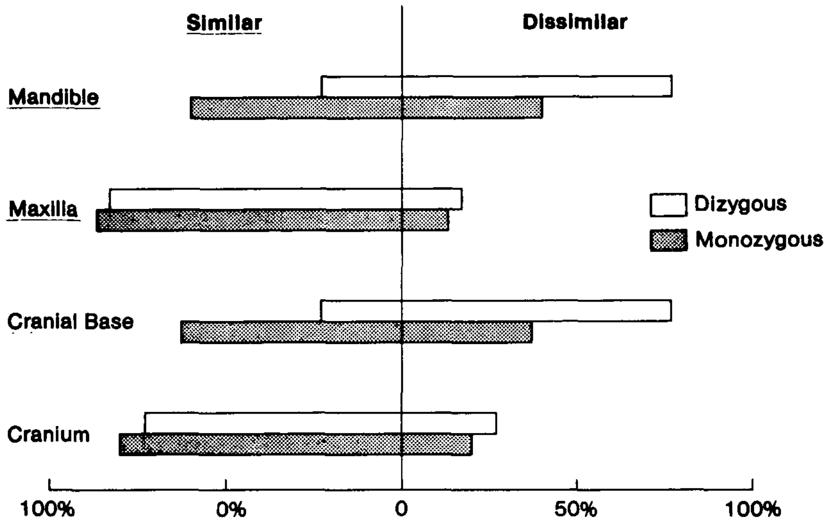
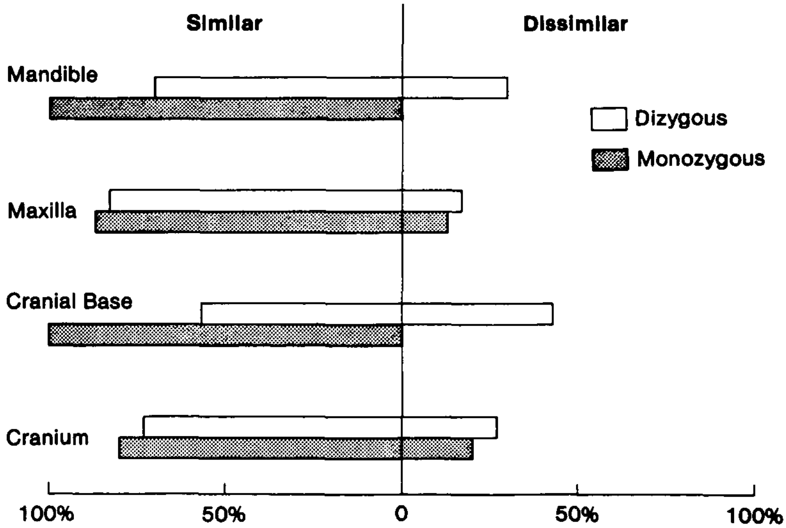


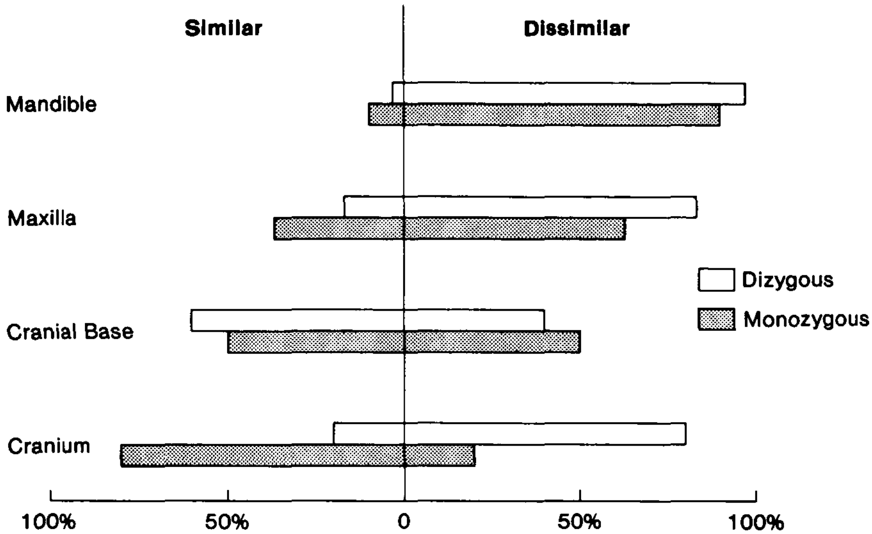
Fig. 7 Mean computer plots representing the dizygous twin pairs superimposed on the anatomic occlusal plane registered at the lower incisal edge.



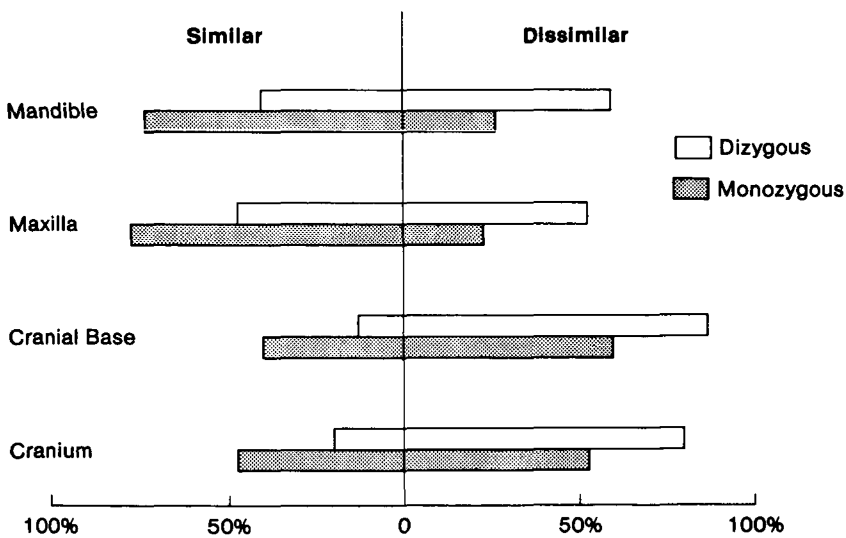
Graph 1
Shape of Individual Craniofacial Components



Graph 2
Shape of Individual Craniofacial Components
Angulation Factors Removed



Graph 3
Spatial Orientation – Superimposed on Sella-Nasion
Registered at Sella



Graph 4
Spatial Orientation – Superimposed on Occlusal Plane
Registered at lower incisor edge

	Monozygous		Dizygous		Fishers's*
	Similar	Dissimilar	Similar	Dissimilar	Exact Test
Cranium	24	6	21	9	0.27
Cranial Base	15	15	18	12	0.30
Maxilla	11	19	5	25	0.07
Mandible	3	27	1	29	0.30

*Significant at or below the 0.05 level

Table 3
Spatial arrangement of craniofacial components as determined by superimposition on the sella-nasion plane.

	Monozygous		Dizygous		Fishers's*
	Similar	Dissimilar	Similar	Dissimilar	Exact Test
Cranium	14	16	6	24	0.02
Cranial Base	12	18	4	26	0.02
Maxilla	23	7	14	16	0.016
Mandible	22	8	12	18	0.009

*Significant at or below the 0.05 level

Table 4
Spatial arrangement of craniofacial components as determined by superimposition of the occlusal plane.

Both groups revealed significant differences in variables measuring relative size; hence it was important to factor out this dimension when assessing craniofacial variation in terms of shape and spatial arrangement (Horowitz et al. 1960). The greatest variation in each group was found in the spatial arrangement of the component parts of the craniofacial complex, rather than within those components.

The evaluation of the shape of the bony components of the craniofacial complex as revealed in a two-dimensional lateral cephalograph suggests that shape of the mandible and cranial base are more variable then the maxilla or cranium. However, when the cranial base and mandible are subdivided into the anterior and posterior cranial base, the corpus, ramus, and symphysis, it is apparent that much of the intra-pair differences in the shape of these bones may be directly assigned to the gonial angle and cranial base flexure.

Thus, this study supports the notion that the cranial base and mandible have areas or zones that may permit spatial adjustment between the component parts of the craniofacial skeleton during growth and development. More specifically, these areas may respond to functional demands

	Monozygous Dizygous	X Difference Monozygous	X Difference Dizygous	Student t Test P Values
SNA	M 80.5±3.7 D 81.5±4.2	M 2.18 SD 1.79	D 2.70° SD 2.22	0.31
SNB	M 77.4±3.4 D 77.8±3.4	M 2.08 SD 1.33	D 2.19 SD 1.79	0.77
Ar-S-Na	M 127.2±4.2 D 124.9±5.9	M 2.55 SD 1.82	D 4.57 SD 3.13	0.003*
Ba-S-Na	M 132.4±4.0 D 131.5±5.8	M 2.48 SD 1.9	D 4.46 SD 3.03	0.003*
Go. Ang.	M 126.8±5.7 D 125.6±4.3	M 2.8 SD 2.32	D 3.85 SD 2.74	0.11
Occl. Md. Pl.	M 22.3±4.6 D 22.2±3.8	M 2.59 SD 2.0	D 4.75 SD 4.47	0.03*
Occl. Pal. Pl.	M 2.58±6.04 D 3.90±4.4	M 3.51 SD 2.08	D 4.97 SD 4.52	0.12
Md.Pal. Pl.	M 25.7±7.51 D 26.1±4.4	M 3.16 SD 2.42	D 4.08 SD 2.87	0.18
Pal/Ba Na	M .4774±.0200 D .4761±.0210	M .013 SD .01	D .029 SD .02	0.0004*
Ar Gn/Ba Na	M 1.027±.0534 D 1.021±.0517	M .019 SD .017	D .032 SD .027	0.035*
Pal/Ar Gn	M .4659±.0260 D .4675±.0273	M .016 SD .01	D .029 SD .02	0.014*
UFH/LFH	M .7809±.0610 D .7807±.0679	M .039 SD .03	D .059 SD .04	0.026*

*Significant at or below the 0.05 level

Table 5
Descriptive statistics

which will affect the ultimate spatial orientation of components of the dentofacial complex.

In the evaluation of spatial arrangement, the mandible, maxilla, cranial base, and cranium were each compared independantly by monozygous and dizygous twin pairing. It was interesting to note the additive effects of variation in position of these individual bones on the total craniofacial complex. This determination required comparing and contrasting the traditional method of superimposition on the anterior cranial base with superimposition on the anatomic occlusal plane (Abraham 1966).

These two methods of superimposition provided very different views of the effects of individual bony variation. Superimposition on the anterior cranial base emphasized the additive effect of variation of the cranial base, the maxilla, the dentition, and the mandible. Due to this additive effect, the greatest difference between the twin pairs observed by this method was in the shape and position of the mandible.

However, superimposition on the occlusal plane showed the variation in the positions of individual bony components was not additive, but rather reflected a harmony with respect to the shape and position of the mandible, especially within the monozygous twin pairs.

This considerable difference in the perspectives provided by superimposing on the occlusal plane and on the anterior cranial base acounts for a significantly greater similarity within the monozygous twin pairs when viewed from an occlusal plane base of superimposition.

The significance of these differences which result from the selection of two different orientations or perspectives becomes apparent when we consider the area of most concern or interest to the orthodontist is the occlusion of the dentition.

Although this study was cephalometric in nature, and only the variation of the craniofacial skeleton was under scrutiny, certain supportable assumptions were made about the dentitions of the monochzygous twins.

It was assumed that monozygous twins have identical occlusions, as manifested by similar Angle molar classifications, tooth size, crowding patterns, and arch shapes and sizes. It was not assumed that individual rotations, overjet or overbite would reflect this same level of similarity, as indicated in the literature (Potter and Nance 1976, Potter et al. 1976).

Dental casts of monozygous twin sets were compared at the beginning of this study to verify identical occlusal anatomy of the mandibular first and second bicuspids in order to corroborate the determination of the original blood studies (Kraus and Furr 1953). At the same time, the dental occlusions of each of the monozygous twin pairs were compared, and all of the monozygous twins included in this study were found to have identical molar relationships and arch form.

If monozygous twin pairs show essentially identical occlusions, what is a reasonable explanation for the considerable variation observed in the bony components of the craniofacial skeleton? The answer is apparent from the relation of the craniofacial complex to the occlusal plane.

Whatever their relationship to the cranial base, the spatial relationship of the maxilla and the mandible in monozygous twin pairs as evaluated from the occlusal plane is both similar and harmonious (Figures 4 and 5). This is not to say that the morphology of the entire mandible must be identical in monozygous twin sets, but rather that position of the tooth-supporting areas of the mandible must be compatible with the position of the comparable areas of the maxilla.

The maintenance of the integrity of the relationship of the tooth supporting areas to each other may very well account for the large variation observed in the gonial area of the mandible, and in the cranial base flexure, within both the monozygous and dizygous twin pairs.

The importance of dental occlusion documented through primate evolution would support the notion that excellent occlusion or articulation must be maintained at all costs (Schultz 1972, Corruccini and Beecher 1982). Hence, there must be an integration and harmony between those elements of the craniofacial skeleton which seem to have a high heredity index with those elements less influenced by heredity and more susceptible to environmental control (Lundstöm 1954).

For example, the cranial base which appears to represent a high component of heritability may dictate the final position of the mandible and related occlusal plane through the temporomandibular articulation. The gonial angle, with a low component of heritability, represents a functional anatomic area of adjustment between the denture-bearing area of the mandible and the ramal articulation with the cranial base (temporomandibular articulation) (Table 7).

The variability observed in the various components of the craniofacial complex in monozygous twins, resulting in a precise relationship of the dentition, supports the argument that the craniofacial skeleton is not under strong genetic control as a total entity (LUNSTRÖM 1954, NAKATA ET AL. 1973, SAUNDERS ET AL. 1980). Rather, it represents a complex integrated balance between those morphologic units under strong genetic control and those units which may accomodate for the variance within the system and provide the structural integrity necessary for functional occlusion.

— Clinical Implications —

Previous investigations have indicated the significance of the polygenic model and the nuclear family to the diagnosis and treatment of the orthodontic patient (HARRIS ET AL. 1973, HARRIS AND KOWALSKI 1976, SAUNDERS ET AL. 1980).

This study refines and extends the implications of this hypothesis to the clinical orthodontist. The analysis of the craniofacial complex in monozygous and dizygous twins indicates that it is the harmony of the craniofacial components closest to the occlusal table which provides the best indication of dental malocclusion. Conversely, the farther a skeletal component is from the occlusal table, the less likely it is to relate to the etiology of malocclusion.

Specifically, this paper strongly supports the utilization of measurements based close to the dentition, such as the *Tweed triangle* (TWEED 1969) and the *Wits* appraisal (JACOBSON 1975). The relationship of the maxilla and the mandible to the occlusal plane are obviously critical to the successful diagnosis, treatment, and retention of orthodontic problems (OPPENHEIM 1928).

Further, this study reveals that in monozygous twin pairs with identical occlusions, it is still possible to identify intrapair variation. Even though the monozygous twins had identical occlusions, their craniofacial complexes were not identical in every detail.

Investigations of the size, shape, and position of the craniofacial components seem to indicate that there may be compensatory mechanisms in areas such as the gonial angle, symphysis, and mandibular-sphenoid articulation which could secondarily influence the integrity of the

	Monozygous	Dizygous
SNA	0.68	0.53
SNB	0.76	0.59
Ar-S-Na	0.80	0.50
Ba-S-Na	0.69	0.51
Go. Ang.	0.71	0.54
Occl. Md. Plane	0.78	0.25
Occl. Pal. Plane	0.75	0.14
Md. Pal. Plane	0.88	0.45
Pal/Ba Na	0.78	0.02
Ar Gn/Ba Na	0.89	0.71
Pal/Ar Gn	0.73	0.28
UFH/LFH	0.75	0.46

Table 6
Correlation Coeffecients (intra-pair variation)

SNA	0.35
SNB	0.21
Ar-S-Na	0.68
Ba-S-Na	0.66
Go. Angle	0.41
Occl. Md. Plane	0.75
Occl. Pal. Plane	0.61
Md. Pal. Plane	0.36
Pal/Ba Na	0.76
Ar Gn/Ba Na	0.63
Pal/Ar Gn	0.71
UFH/LFH	0.52

Table 7
Heritability Coeffecients

maxillary-mandibular relationship (WATNICK 1969, MCNAMARA 1973, PETROVIC ET AL. 1975).

If this assumption is reasonable, then the utilization of orthodontic procedures to influence mandibular growth with appropriate reciprocal maxillary effects has a rational biologic model. At the same time, twin studies clearly indicate that the craniofacial matrix is under substantial genetic control, and the redirection of a basic growth pattern may be modified only within biologic limits which are harmonious for that patient Nakata et al. 1973).

Further definition of the mechanisms by which these compensatory areas are altered to accommodate to a functioning occlusion is desirable, as this could be extended to clinical practice and perhaps shed some light on the use of functional appliances and the underlying mechanisms by which they produce the observed results. A/O

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