Original Article

Cephalometric craniofacial features in Saudi parents and their offspring

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ABSTRACT

Objective: To estimate the correlation and heritability values of craniofacial variables between parents and their offspring.

Materials and Methods: The sample comprised 24 Saudi families; each family consisted of father, mother, son, and daughter. Lateral cephalometric radiographs were taken for each family member. Twenty-eight angular, linear, and proportional cephalometric variables were measured. Interfamilial correlations and heritability (h^2) values were estimated among father-son, father-daughter, mother-son, and mother-daughter pairings.

Results: The most similar angular measurements between parents and offspring were related to mandibular variables, which were as follows: MP-SN°, MP-FH°, SNB°, and SNPog°; facial height dimensions and mandibular body length were among the highest similar linear variables. Lower facial height percentage had greater resemblance to parents with regard to proportional measurements. Both the correlation coefficients and the heritable values of these characteristics were stronger in the father-offspring than the mother-offspring pairings. The daughters' cephalometric craniofacial characteristics were more affected by the parents than were those of the sons.

Conclusions: The overall correlation and h^2 mean values for the three types of measurements showed stronger values in the father-offspring than the mother-offspring groups, with the father-daughter pairings more significant than the father-son groups. (*Angle Orthod.* 2010;80:1010–1017.)

KEY WORDS: Cephalometrics; Heritability; Craniofacial features; Offspring

INTRODUCTION

Human genetics has been a subject of interest for many researchers over the years. Previous studies of families and twins have provided us with the knowledge that genetic factors play a crucial role in craniofacial growth and development. Different methods have been developed to demonstrate inheritance, the resemblance between relatives being the simplest form, by comparing the trait or traits in question in closely related individuals.[1] Until recently, the vast majority of research has focused on the heritability of malocclusion and craniofacial morphology among siblings, with the twin model being the most popular method used.[1–9] Research comparing parents with their offspring has been limited because of the fact that tooth loss, restorative, prosthetic, and orthodontic treatment of older generations makes these investigations difficult.

Hughes and Moore[10] were among the earliest investigators to subscribe to a multiple gene concept of inheritance in the craniofacial complex. Dentofacial and anthropometric records were taken for 150 families—parents and offspring—along with roentgenograms and dental casts on 26 of these families. Investigators observed that craniofacial growth and morphology were under strong hereditary control and expressed this concept in percentages of heritability between parents and siblings. In 1967, Fernex et al.[11] concluded from their study that boys displayed more similarity to their parents than girls. With regard to facial skeletal structures, mothers were responsible for transmitting these variables to their sons more

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frequently than to their daughters. Saunders et al.[12] utilized lateral cephalograms to study the similarities in craniofacial dimensions between family members from the Burlington Growth Centre sample. They compared parents with offspring, and siblings with siblings. Their results showed a high level of significant correlation between first-degree relatives, and investigators concluded that the use of multiple measurements from both parents is the best method of predicting a child's craniofacial dimension. Ichinose et al.[13] studied the similarity in maxillofacial morphology between Japanese parents and their growing children aged 6 years and older. Significantly greater parent-offspring heritability was detected for maxillofacial variables than for dentoalveolar variables. This was apparent more often in female than in male offspring.[13] Johannsdottir et al.[14] estimated the heritability of different cephalometric parameters between parents and their offspring (6–18 years old) in an Iceland population. They found a statistically significant heritability pattern in the daughter-father and daughter-mother groups—greater than with sons and their parents. Daughters showed similar heritability to both parents at both age levels, but more variables were highly significant in the daughter-father groups. Sons showed stronger heritability to their mothers at both ages.

It is well established that parental data are useful in predicting craniofacial dimensions and facial growth of the child. Therefore, it is of interest to establish the heritability pattern between them. Because a limited number of studies on this matter have been conducted, it was the aim of this study to determine the influence of heredity of craniofacial form between parents and their offspring, and to correlate the similarity pattern between both among Saudi families.

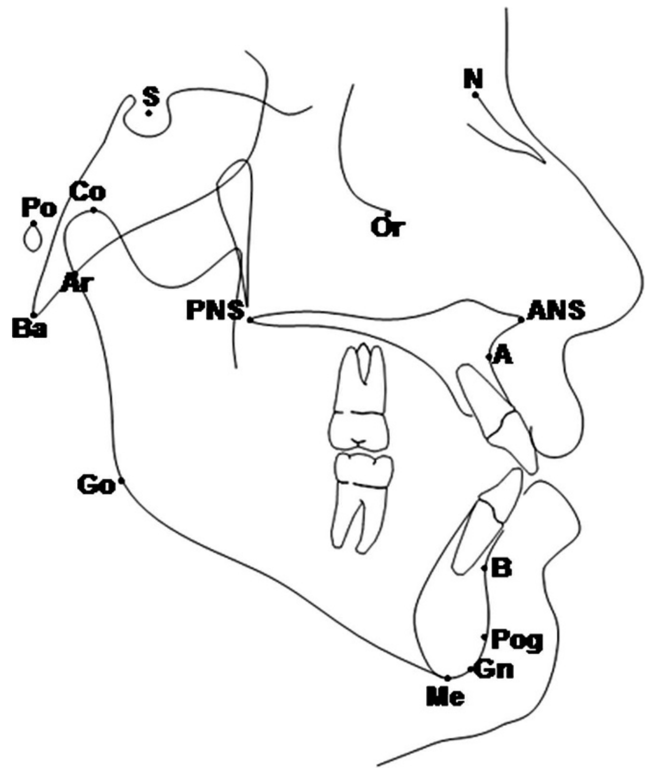

Figure 1. Cephalometric landmarks used in the study.

MATERIALS AND METHODS

Study materials included lateral cephalometric radiographs obtained from the Dental College in King Saud University in Riyadh for 24 Saudi families; each family consisted of father, mother, son, and daughter. Inclusion criteria applied for family selection for the sample were as follows: children 17 years of age or older; permanent dentition stage; no extensive prosthetic treatment or missing teeth; no history of orthodontic treatment; no abnormal dental habits such as thumb sucking, mouth breathing, and nasal blockage; no congenital disorders such as cleft lip and palate or craniofacial deformity; all family members blood relatives (no adopted or stepchildren); and no pregnant mothers or daughters.

Radiographs were taken with the use of the Orthopantomograph OP 100 (Instrumentarium Dental Inc, Milwaukee, Wis), which is located in the College of Dentistry, King Saud University. For standardized positioning, a cephalostat was used to maintain the subject's head in a constant relationship to the film. This in turn standardized the distance of the subject to the film, the x-ray exposure, and the magnification exposure. All subjects were asked to sit upright looking straight forward, with a lead apron on their chests. Ear rods were placed into the ear canals in a comfortable position, and the orbital pointer was accurately positioned. All radiographs were traced by the same investigator. Fifteen landmarks were identified (Figure 1) and recorded, and angular, linear, and proportional measurements were obtained (Table 1 displays the measurements with their corresponding definitions). The midpoint of a bilateral structure was taken if present.[15] Radiographs were scanned at a resolution of 150 dots per inch (dpi) using an Epson scanner (Epson Perfection 4990 PHOTO, Nagano, Japan), and then were digitized using commercially available software (Dolphin Imaging 10.0 Build 52 Premium, Patterson Dental Supply, Chatsworth, Calif). Landmark identification of the 15 landmarks was carried out by manual dot tracing on the digital image using a mouse-driven cursor in a predetermined sequence. Cephalometric measurements were automatically calculated by using the software.

Method error was assessed by using both the Dahlberg method and the coefficient of reliability.[16,17]

Table 1. Cephalometric Measurements Used in the Study and Their Definitions

Measurements	Variables	Definitions
Angular	SNA	Angle determined by points S, N, and A.
	SNB	Angle determined by points S, N, and B.
	ANB	Angle determined by points A, N, and B.
	SNPog	Angle determined by points S, N, and Pog.
	BaSN	Angle determined by points Ba, S, and N.
	FH-SN	Angle formed by Frankfort horizontal plane and SN plane.
	NA-APog	Angle formed by NA plane and APog plane.
	AB-Facial Plane	Angle formed by AB plane to facial plane (N-Pog).
	FH-NPog	Angle formed by Frankfort horizontal plane and NPog plane.
	SGn-FH	Angle formed by SGn plane and Frankfort horizontal plane.
	PP-MP	Angle formed by PP plane and MP plane.
	MP-SN	Angle formed by MP plane and SN plane.
	MP-FH	Angle formed by MP plane and Frankfort horizontal plane.
	ArGoMe	Angle determined by Ar, Go, and ME.
	SN-PP	Angle formed by SN plane and PP plane.
Linear	S-N	Distance between points S and N in mm.
	Na-Me	Distance between points N and Me in mm.
	N-ANS	Distance between points N and ANS in mm.
	ANS-Me	Distance between points ANS and Me in mm.
	S-Go	Distance between points S and Go in mm.
	Ar-Go	Distance between points Ar and Go in mm.
	Go-Me	Distance between points Go and Me in mm.
	Ar-Gn	Distance between points Ar and Gn in mm.
	Co-Gn	Distance between points Co and Gn in mm.
	ANS-PNS	Distance between points ANS and PNS in mm.
	Co-A	Distance between points Co and A in mm.
Proportional	LFH, %	Lower facial height percentage.
	Co-Gn/Co-A	Maxillary – mandibular length difference.

Descriptive analysis was calculated for each cephalometric measurement. For each variable, a comparison between the sons and the father, and between the sons and the mother, was calculated. Daughters' variables were also compared with both the father and the mother. Calculations were performed using two statistical methods: the Pearson correlation coefficient and the heritability test. The formula of heritability between parents and offspring is twice the regression coefficient, *b*, of the offspring on the parent[18]: $h^2 = 2 \times b$.

Heritability estimates should fall between 0 and 1. For any trait, a heritability estimate of 1 is expressed theoretically with no environmental influence; on the other hand, an estimate of 0 defines the trait with no heritable influence. A midway value of 0.5 would have its variability influenced by both environment and genetics. However, heritability estimates may exceed the value of 1 because in humans, the method used for estimating it operates under several simplifying assumptions that may be incorrect, or the error may be due to sampling fluctuation and/or environmental covariation.[7,8,19–21] Two points must be kept in mind when estimating heritability. First, it must be noted that heritability estimates do not state for sure that a certain trait is determined to a specific degree by genetic and environmental factors in a single individual. Second, these estimates are not predictive; rather they are descriptive of variances within a sample at a given time.[22]

RESULTS

Slightly increased readings regarding Dahlberg's double determination method were detected for cephalometric landmarks SNB°, gonial angle, SN mm, and ArGo mm, as shown in Table 2. However, readings for the coefficient of reliability were 0.9 and higher, indicating a high correlation between the first and second measurements for all cephalometric variables. Table 3 represents the age ranges, as well as the mean age value, for fathers, mothers, sons, and daughters.

Pearson's Correlation between Parents and Offspring

Results of the correlation between parents and their offspring are presented in Table 4 for the corresponding angular, linear, and proportional measurements. Statistically significant correlations for the corresponding three groups of measurements were found more often in the father-offspring groups than in the mother-offspring groups, with daughters resembling their fathers more than sons for all three types of variables

Table 2. Method Error of 18 Repeated Radiographs for Cephalometric Measurements as Evaluated by Dahlberg's Double Determination Method and Coefficient of Reliability

Measurements	Variables	Dahlberg's Method	Coefficient of Reliability
Angular	SNA	0.529	0.984
	SNB	1.675	0.900
	ANB	0.353	0.986
	SNPog	0.466	0.986
	BaSN	0.901	0.977
	FH-SN	0.622	0.922
	NA-APog	0.855	0.984
	AB-Facial Plane	0.584	0.976
	FH-NPog	0.512	0.996
	SGn-FH	0.436	0.997
	PP-MP	0.545	0.994
	MP-SN	0.531	0.996
	MP-FH	0.533	0.997
	ArGoMe	1.491	0.983
	SN-PP	0.593	0.979
Linear	S-N	1.473	0.944
	Na-Me	0.946	0.990
	N-ANS	0.774	0.971
	ANS-Me	0.829	0.986
	S-Go	0.934	0.989
	Ar-Go	1.445	0.949
	Go-Me	0.928	0.987
	Ar-Gn	1.015	0.990
	Co-Gn	0.682	0.995
	ANS-PNS	0.844	0.979
	Co-A	0.828	0.975
Proportional	LFH, %	0.498	0.940
	Co-Gn/Co-A	0.764	0.977

measured. Statistically stronger correlations in angular measurements were related to the mandible (SNB, SNPog, PP-MP, MP-SN, ArGoMe), while facial height dimensions and mandibular body length were among the highest correlated linear variables (Na-Me, N-ANS, ANS-Me, S-Go). With regard to proportional measurements, both lower facial height (LFH) and the maxillary -mandibular length difference (Co-Gn/Co-A) had significant values.

Table 5 displays the mean value for each of the three measurement groups. The table shows that father-offspring correlations were higher than mother-offspring correlations. Stronger correlations were also found between parents-daughter groups than between parents-son groups for all measurements, except linear measurements, for which higher correlations were present in mother-son groups.

Heritability Estimates between Parents and Offspring

Heritability estimates for the corresponding angular measurements are presented in Table 6. Generally, father-offspring h^2 values were higher than those in the

Table 3. Age Range and Mean Age for the 24 Saudi Families

	Age, min	Age, max	Mean
Father	40	65	53
Mother	35	60	45
Son	17	35	21
Daughter	17	28	19

mother-offspring group. As can be noted, significant values were present mainly in the father-daughter group (SNB, SNPog, AB-facial plane). The sons showed significant heritability patterns with their fathers regarding FH-Sn plane, and with their mothers regarding the ArGoMe angle. Any estimate >1 was considered a meaningless value because heritability estimates should be between the values of 0 and 1.

Heritability estimates for the linear measurements are presented in Table 7. Significant h^2 values were found in the father-daughter group in both S-N and Co-Gn, as well as in the mother-son group in S-Go and Go-Me. With regard to proportional measurements, significant h^2 values were found only in the father-daughter group with both LFH and the maxillary-mandibular length difference (Co-Gn/Co-A) (Table 8).

Table 9 shows that the mean h^2 values for all three measurements were higher in father-offspring groups than in mother-offspring groups, with the daughters resembling fathers more than the sons did.

DISCUSSION

The aim of this study was to examine the resemblance of several cephalometric craniofacial variables between Saudi parents and their offspring. The ages of the offspring were chosen to be postpubertal so as to minimize the effects of variation related to timing and rate of growth. Previously reported research included offspring of different ages compared with their parents, starting as early as 4 years[9] and 6 years of age.[13,14] Hunter in 1965 mentioned higher and more statistically significant correlations with their postpubertal offspring study from a previous series of studies analyzing dentofacial relationships between parents and growing offspring.[23]

No restriction in the type or severity of malocclusion was applied in this study to exclude any bias in sample selection, as recommended by several previous studies.[7,8,13] Regarding the cephalometric measurements studied in this research, they were chosen because of their widespread use in cephalometrics and their value in orthodontic treatment and research; they were also the most commonly repeated measurements utilized in previous heredity craniofacial studies.

It is well known that the final result of craniofacial morphology is the combination of both genetic and

Table 4. Correlation Coefficients between Corresponding Angular, Linear, and Proportional Measurements in the Parents-Offspring Group

Measurements	Variables	Father/Son	Mother/Son	Father/Daughter	Mother/Daughter
Angular	SNA	0.302	0.334	0.334	0.219
	SNB	0.064	0.089	0.557**	0.159
	ANB	0.024	0.01	0.494*	0.413*
	SNPog	0.01	0.08	0.527**	0.031
	BaSN	0.146	0.274	0.315	0.314
	FH-SN	0.445*	0.130	0.074	0.034
	NA-APog	0.062	0.076	0.5*	0.341
	AB-Facial Plane	0.054	0.073	0.437*	0.419*
	FH-NPog	0.03	0.252	0.110	0.122
	SGn-FH	0.197	0.212	0.120	0.02
	PP-MP	0.639***	0.354	0.666***	0.234
	MP-SN	0.524**	0.220	0.671***	0.041
	MP-FH	0.495*	0.249	0.339	0.167
	ArGoMe	0.308	0.497*	0.478*	0.241
	SN-PP	0.036	0.098	0.463*	0.128
Linear	S-N	0.391	0.208	0.418*	0.288
	Na-Me	0.736***	0.267	0.676***	0.014
	N-ANS	0.447*	0.100	0.465*	0.033
	ANS-Me	0.744***	0.342	0.720***	0.158
	S-Go	0.314	0.405*	0.568***	0.222
	Ar-Go	0.038	0.181	0.337	0.014
	Go-Me	0.160	0.465*	0.256	0.122
	Ar-Gn	0.207	0.349	0.391	0.067
	Co-Gn	0.299	0.315	0.358	0.045
	ANS-PNS	0.231	0.125	0.410*	0.044
	Co-A	0.079	0.085	0.600**	0.083
Proportional	LFH, %	0.335	0.181	0.568***	0.222
	Co-Gn/Co-A	0.227	0.01	0.561**	0.110

* $P \leq .05$; ** $P \leq .01$ *** $P \leq .001$.

environmental influences and therefore is multifactorial. Clinical perception suggests that heredity plays a major role in craniofacial structure. Heritability, in a narrow sense, is obtained from the parents-offspring correlation and expresses the proportion of the total phenotype that is contributed by additive genetic variance—the genotype. This additive component is what determines the degree of resemblance between relatives, representing the portion of genetic variance that can be used to predict the expected measurement value in an individual from relatives' observations. Confirming that a certain genetic influence affects a trait is a primary step toward additional genetic studies (using DNA markers) to search for the genome that appears to be associated with a given trait.[22]

Table 5. Overall Mean Values of Correlation Coefficients Corresponding to Angular, Linear, and Proportional Measurements in the Parents-Offspring Group

Variables	Offspring	Father	Mother
Angular	Son	0.222	0.176
	Daughter	0.405	0.192
Linear	Son	0.331	0.258
	Daughter	0.543	0.111
Proportional	Son	0.281	0.095
	Daughter	0.564	0.166

Heritability values fall within the range of 0 to 1. So, in principle, a heritability of 0 may be reached if no genetic variation is applicable in a sample having the same genotype. On the other hand, heritability could approach 1.0 if no environmental differences are detected in the sample studied. However, estimates may exceed this range, as we saw in our results and considered a ''meaning-less value.'' This may occur as the result of sampling fluctuation and/or environmental covariation (eg, enhanced acquired similarity)[7,8,14,20,21,24] and can be explained by the ''cohabitational effect,'' which causes family members to look alike not only because of genetics, but because of the shared environment they live in, influencing phenotypic similarities and enhancing phenotypic correlations.[25] This point may be applicable to the present Saudi sample studied, which has a closer family living relationship and style than are seen in Western societies. In this study, when the heritability value of a variable was greater than 1, we were unable to use it for comparison. The standard error was used as a measured estimation of data accuracy of given h^2 values. The smaller the standard error, the more reliable and valid the h^2 value was.

A general overview of correlation results revealed a smaller number of statistically significant correlations

Table 6. Listing of Heritability Estimates for the Corresponding Angular Measurements and Standard Errors in Parents-Offspring Groups[a]

Variables	Offspring	Father h^2	Father SE	Mother h^2	Mother SE
SNA	Son	0.57	0.19	0.07	0.27
	Daughter	0.57	0.17	0.51	0.24
SNB	Son	0.12	0.21	0.29	0.34
	Daughter	0.85**	0.13	0.40	0.26
ANB	Son	0.03	0.16	0.02	0.21
	Daughter	1.03[b]*	0.19	1.12[b]*	0.26
SNPog	Son	0.01	0.14	0.10	0.14
	Daughter	0.81**	0.14	0.04	0.16
BaSN	Son	0.23	0.16	0.43	0.16
	Daughter	0.48	0.15	0.48	0.15
FH-SN	Son	0.84*	0.18	0.20	0.16
	Daughter	0.11	0.16	0.04	0.13
NA-APog	Son	0.10	0.18	0.16	0.22
	Daughter	1.05[b]*	0.19	0.88	0.25
AB-Facial Plane	Son	0.06	0.13	0.13	0.19
	Daughter	0.81*	0.17	1.13[b]*	0.26
FH-NPog	Son	0.05	0.19	0.47	0.19
	Daughter	0.22	0.21	0.25	0.22
SGn-FH	Son	0.37	0.19	0.36	0.18
	Daughter	0.23	0.21	0.03	0.19
PP-MP	Son	1.06[b]***	0.13	0.84	0.23
	Daughter	1.13[b]***	0.13	0.57	0.25
MP-SN	Son	1.09[b]**	0.18	0.51	0.24
	Daughter	1.17[b]***	0.13	0.08	0.21
MP-FH	Son	1.10[b]*	0.20	0.57	0.23
	Daughter	0.77	0.22	0.38	0.24
ArGoMe	Son	0.58	0.19	0.85*	0.15
	Daughter	1.12[b]*	0.21	0.51	0.21
SN-PP	Son	0.53	0.29	0.22	0.23
	Daughter	1.18[b]*	0.24	0.26	0.21

[a] h^2 indicates heritability; SE, standard error.
[b] Meaningless value.
* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

between parents and offspring, as well as different h^2 values for the corresponding measured craniofacial variables, as compared with previously reported studies. This may be attributed to variation in sample number, age, and sex and racial differences reported in other studies.[7,8,14,23,26,27]

The most noticeable feature was stronger correlations and h^2 values between fathers and their offspring than between mothers and their offspring. This feature was consistent with the findings of Hunter[23] and Nakata et al.[26]; however, it did not confirm the results of Saunders et al.[12] and Nakisama et al.,[27] who found no statistically significant difference in the value of any parents-offspring correlations.

More significant correlations and stronger heritability were found in parent-daughter pairings than in parent-son pairings for the corresponding craniofacial variables. Several studies agree with our findings in that daughters were more affected by their parents than were sons.[13,14,28] However, others found no significant differences between sons and daughters and their parents.[12,23]

Table 7. Listing of Heritability Estimates for the Corresponding Linear Measurements and Standard Errors in Parents-Offspring Groups[a]

Variables, mm	Offspring	Father h^2	Father SE	Mother h^2	Mother SE
S-N	Son	0.85	0.21	0.26	0.13
	Daughter	0.87*	0.20	0.34	0.12
Na-Me	Son	1.47[b]***	0.14	0.51	0.19
	Daughter	1.12[b]***	0.13	0.02	0.17
N-ANS	Son	1.35[b]*	0.28	0.17	0.18
	Daughter	1.18[b]*	0.24	0.04	0.15
ANS-Me	Son	1.16[b]***	0.11	0.75	0.22
	Daughter	1.07[b]***	0.11	0.33	0.22
S-Go	Son	0.73	0.23	0.54*	0.13
	Daughter	0.47	0.14	0.01	0.08
Ar-Go	Son	0.10	0.28	0.30	0.17
	Daughter	0.44	0.17	0.13	0.11
Go-Me	Son	0.47	0.30	0.70*	0.14
	Daughter	0.96	0.24	0.08	0.13
Ar-Gn	Son	0.52	0.26	0.58	0.16
	Daughter	0.66	0.18	0.05	0.13
Co-Gn	Son	0.60	0.20	0.51	0.16
	Daughter	0.73*	0.17	0.06	0.15
ANS-PNS	Son	0.50	0.22	0.17	0.14
	Daughter	1.18[b]**	0.16	0.10	0.13
Co-A	Son	0.21	0.28	0.11	0.14
	Daughter	0.56	0.26	0.03	0.13

[a] h^2 indicates heritability; SE, standard error.
[b] Meaningless value.
* $P \leq .05$; ** $P \leq .01$; *** $P \leq .001$.

In the current study, linear measurements had higher heritability estimates than angular variables in all parents-offspring pairings except in the mother-daughter group. This may be due to the fact that linear measurements have greater genetic determination than angular measurements.[26] Johannsdottir et al.[14] reported higher heritability values related to mandibular than to maxillary variables. This was in concordance with what was found in this study regarding both angular (SNB°, SNPog°, MP-SN°, MP-FH°, ArGoMe°) and linear mandibular measurements (GoMe mm). SNA° had relatively stronger h^2 estimates in father-offspring than in mother-offspring groups. Mandibular

Table 8. Listing of Heritability Estimates for the Corresponding Proportional Measurements and Standard Errors in Parents-Offspring Groups[a]

Variables	Offspring	Father h^2	Father SE	Mother h^2	Mother SE
LFH, %	Son	0.49	0.14	0.37	0.21
	Daughter	0.97*	0.15	0.53	0.25
Co-Gn/Co-A	Son	0.29	0.13	0.02	0.27
	Daughter	0.75**	0.11	0.29	0.28

[a] h^2 indicates heritability; SE, standard error.
* $P \leq .05$; ** $P \leq .01$.

Table 9. Overall Mean Values of Heritability for the Corresponding Angular, Linear, and Proportional Measurements in the Parents-Offspring Groups

Variables	Offspring	Father	Mother
Angular	Son	0.449	0.348
	Daughter	0.768	0.445
Linear	Son	0.723	0.418
	Daughter	0.84	0.108
Proportional	Son	0.39	0.195
	Daughter	0.86	0.41

angular measurements such as SNB, SNPog, and gonial angles showed greater similarities in opposite parents-offspring sexes, mother-son, and father-daughter pairings, and especially stronger values in father-daughter pairings. This was in agreement with Johannsdottir et al.[14] but was not consistent with the findings of Saunders et al.,[12] who found SNB° to be significant in all other parents-offspring groups. ANB° was significantly correlated only in parent-daughter pairings; however, it was more strongly correlated in father-offspring pairings than in mother pairings. This was supported by the Saunders et al.[12] study.

Anterior facial height dimensions (Na-Me, Na-ANS, ANS-Me, and LFH%) were among the highest correlations found in this study, especially in the father-offspring pairings; lower facial height length (ANS-Me) was the strongest and was almost the same in both offspring sexes. This was in agreement with Litton et al.[29] It was also found that lower anterior facial height (ANS-Me) had greater heritability than did both total and upper anterior facial heights (Na-Me and Na-ANS) and posterior facial height (S-Go). Hence, this leads to the notion that total facial height heritability might be attributed more to its lower part than to its upper part. It must be kept in mind that heritability is only a descriptive statistic of a given sample in a given environmental condition.[30]

Similar to mandibular angular variables, mandibular linear measurements had higher h^2 values within both mother-son and father-daughter pairings. Several previous studies found fathers' linear mandibular values to be a more efficient predictor of offspring's linear mandibular measurements[12,23,26]; however, others reported greater similarity in these measurements between offspring and their mothers.[14,27] Finally, most of the maxillary measurements (SN-PP°, SN mm, ANS-PNS mm, and Co-A mm) and maxillomandibular variables (ANB°, NA-APog°, AB to facial plane°, PP-MP°, PP-MP°, and Co-Gn/Co-A) showed greater similarity within father-daughter pairings.

CONCLUSIONS

- Several cephalometric craniofacial characteristics have correlations and are heritable between intrafamilial parents-offspring groups.
- The most similar angular measurements between parents and offspring are related to mandibular variables, including MP-SN°, MP-FH°, SNB°, and SNPog°.
- Facial height dimensions and mandibular body length are among the highest similar linear variables between parents and offspring.
- The lower facial height percentage of offspring has greater resemblance to their parents with regard to proportional measurements.
- Both the correlation coefficients and the heritable values of these characteristics are stronger in father-offspring than in mother-offspring pairings.
- Daughters' cephalometric craniofacial characteristics are more affected by their parents than are those of sons.

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REFERENCES

1. Harris JE, Kowalski CJ, Walker SJ. Intrafamilial dento-facial associations for Class II division 1 probands. *Am J Orthod*. 1975;67:563–570.
2. Hunter WS, Balbach DR, Lumpier DE. The heritability of attained growth in the human face. *Am J Orthod*. 1970;58:128–134.
3. Harris JE. Genetic factors in the growth of the head: inheritance of the craniofacial complex and malocclusion. *Dent Clin North Am*. 1975;19:151–160.
4. Corruccini R, Potter RHY. Genetic analysis of occlusal variation in twins. *Am J Orthod*. 1980;78:140–154.
5. Lundstrom A, McWilliam JS. A comparison of vertical and horizontal variables with regard to heritability. *Eur J Orthod*. 1987;9:104–108.
6. Boraas JC, Messer LB, Till MJ. A genetic contribution to dental caries, occlusion, and morphology as demonstrated by twins reared apart. *J Dent Res*. 1988;67:1150–1155.
7. Harris EF, Johnson MG. Heritability of craniometric and occlusal variables: a longitudinal sib analysis. *Am J Orthod Dentofacial Orthop*. 1991;90:258–268.
8. King L, Harris EF, Tolley EA. Heritability of cephalometric and occlusal variables as assessed from siblings with overt malocclusions. *Am J Orthod Dentofacial Orthop*. 1993;104:121–131.
9. Manfredi C, Martina R, Grossi GB, Giuliani M. Heritability of 39 orthodontic cephalometric parameters on MZ, DZ twins and MN-paired singletons. *Am J Orthod Dentofacial Orthop*. 1997;111:44–51.
10. Hughes BO, Moore GR. Heredity, growth, and the dento-facial complex. *Angle Orthod*. 1941;11:217–222.
11. Fernex E, Hauenstein P, Roche M. Heredity and craniofacial morphology. *Trans Eur Orthod Soc*. 1967;11:239–257.
12. Saunders SR, Popvich F, Thompson GW. A family study of craniofacial dimensions in the Burlington Growth Centre sample. *Am J Orthod*. 1980;78:394–403.
13. Ichinose M, Nakasima A, Hu JR. Growth-related changes in familial resemblance of maxillofacial morphology. *J Craniofac Genet Dev Biol*. 1993;13:35–46.

14. Johannsdottir B, Thorarinsson F, Thordarson A, Magnusson TE. Heritability of craniofacial characteristics between parents and offspring estimated from lateral cephalograms. *Am J Orthod Dentofacial Orthop*. 2005;127:200–207.
15. Jacobson A, Jacobson RL. *Radiographic Cephalometry: From Basics to 3-D Imaging.* 2nd ed. Chicago, Ill: Quintessence Publishing; 2006.
16. Dahlberg A. *Statistical Methods for Medical and Biological Students*. New York, NY: Interscience Publications; 1940.
17. Guilford JP, Fruchter B. *Fundamental Statistics in Psychology and Education.* 6th ed. New York, NY: McGraw-Hill Book Company; 1984.
18. Falconer DS. *Introduction to Quantitative Genetics.* 4th ed. Essex: Pearson Education Limited; 1989.
19. Townsend GC, Brown T. Heritability of permanent tooth size. *Am J Phys Anthrop*. 1978;49:497–504.
20. Hu JR, Nakasima A, Takahama Y. Heritability of dental arch dimensions in humans. *J Craniofac Genet Dev Biol*. 1991;11:165–169.
21. Graber TM, Vanarsdall RL, Vig KWL. *Orthodontics: Current Principles and Techniques.* 4th ed. St Louis: Elsevier Mosby; 2005.
22. La Buda MC, Gottesman II, Pauls DL. Usefulness of twin studies for exploring the etiology of childhood and adolescent psychiatric disorders. *Am J Med Genet*. 1993;48:47–59.
23. Hunter WS. A study of inheritance of craniofacial characteristics as seen in lateral cephalograms of 72 like-sexed twins. *Rep Congr Eur Orthod Soc*. 1965;41:59–70.
24. Harris EF, Smith FO. A study of occlusion and arch widths in families. *Am J Orthod*. 1980;78:155–163.
25. Garn SM, Cole PE, Bailey SM. Living together as a factor in family-line resemblances. *Hum Biol*. 1979;51:565–587.
26. Nakata M, Yu P, Davis B, Nance WE. The use of genetic data in the prediction of craniofacial dimensions. *Am J Orthod*. 1973;63:471–480.
27. Nakisama A, Ichinose M, Nakata S. Genetic and environmental factors in the development of so-called pseudo- and true mesiocclusions. *Am J Orthod Dentofacial Orthop*. 1986;90:106–116.
28. Suzuki A, Takahama Y. A cephalometric study on the similarity of craniofacial morphology between children and their parents. *J Jpn Orthod Soc*. 1988;47:697–719. [Abstract in English.]
29. Litton F, Ackermann LV, Isaacson RJ, Shapiro BL. A genetic study of Class III malocclusion. *Am J Orthod*. 1970;58:565–577.
30. Hartsfield JK Jr. Development of the vertical dimensions: nature and nurture. *Semin Orthod*. 2002;8:113–119.