The Interrelationships Between Facial Areas and Other Body Dimensions

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Human growth is characterized by considerable variation in the ages at which children reach similar stages of development. For this reason chronological age is not a reliable guide of progress towards physiological maturity.[4] The developmental status of a child can better be expressed in terms of other body dimensions such as stature and weight which are composite human measurements and sum up all increments in growth at that age. Skeletal maturation is another measure of a child's progress toward maturity.[19] These measurements are easily taken and are valuable for predicting the future growth and development of the dentofacial complex. Angular and linear measurements are important for studies done on a longitudinal basis. However, measurements of different irregular areas on tracings of lateral cephalograms are not a common practice in our science. The body structures are usually measured in one dimension (length, width, etc.) or in three dimensions (volume, weight), but not in two dimensions. The measurements in two dimensions are equally important and particularly useful in roentgenographic studies.

The premenarchial period in girls is the time when greatest changes in growth rates and directions are expected. Therefore, the study during this period should offer the best chance to observe their growth patterns.

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The objectives of this study are defined as follows:

1. To find the value of various physical indices of the overall developmental status and the nature of the interrelationships among these indices.
2. To measure and compare the growth and sizes of the various facial areas with the above physical characteristics and to determine their interrelationships.
3. To suggest a method by which growth of the facial areas can be expressed in terms of other measurements of the body.
4. To use and observe the utility of a method of taking head and hand X-ray pictures on a single X-ray film, as suggested by Grave,[10] in routine orthodontic practice.

REVIEW OF LITERATURE

Buehl and Pyle[5] analyzed the association between age at ossification of the ulnar metacarpophalangeal sesamoid and menarche and gave correlation coefficients of 0.75 and 0.71.

Simmons and Gruelich[20] investigated menarchial age, height, weight and skeletal age taken from X-rays of 200 girls of 7 to 17 years of age. They observed that the skeletal age was better correlated to menarchial age than with weight and height.

Rose[18] has correlated facial areas with body stature, weight, chronological age and skeletal age by examining 125 cephalometric roentgenograms and carpal films in the age range of 9 to 18 years of both sexes. His conclusions were:

1. Chronological and skeletal ages proved an ineffectual guide to the growth and development of facial areas in the parapuberal period, whereas stature and body weight proved the best indicators.

2. Close correlation existed between total maxillary and total mandibular areas. The orbitoethmoid area showed little, if any, relation to other facial areas or height and weight. Moreover, the orbitoethmoid area grows quite differently from the maxillary and mandibular areas and its style of growth may be said to approach the neural type.

Lauterstein[16] examined 132 white children from ages 61 months to 82 months and showed that chronological age bore a positive relationship to bone age.

Green[11] studied the interrelationship among height, weight, chronological, dental and skeletal ages. He determined statistically the nature of the relationship among them and showed that chronological age was more highly correlated with dental age than the other variables. Skeletal age, height and weight showed a slight tendency to form a factor which is possibly controlled to some degree by the same forces of growth and development.

Hunter[13] from a longitudinal study of 34 girls and 25 boys showed that the maximum facial growth was coincident with maximum growth in height in the majority of the subjects and the skeletal age range at the onset of pubertal growth period in height was one half the chronological age range in males. There was little difference between chronological and skeletal age ranges at the onset in females. Final facial size was attained earlier in females in relation to skeletal age. In males, a small amount of facial growth occurred after the skeletal age of 18 years and probably after skeletal maturation was complete.

Björk and Helm[2] demonstrated the close association between the age at maximum growth in height and the age when the ossification of the ulnar metacarpophalangeal sesamoid occurred and also in girls, the age at menarche. They showed sesamoid appearance preceding menarche by 2.5 years on an average and maximum height increases by about one year in girls and nine months in boys.

Materials and Method

The data were obtained from standard lateral headplates and the right hand-wrist X-rays of a group of 35 girls. The subjects were selected at random from a girls' school in Asarwa, Ahmedabad. All of the subjects of the sample satisfied the following criteria:

1. From a Hindu family residing in Gujarat whose mother-tongue should be Gujarati.
2. Age should be within 120 months to 144 months.
3. Must not have started menstruation.
4. Should be from middle to high socioeconomic group.
5. Clinically, should have normal facial features and a Class I molar relationship (very mild crowding in maxillary and mandibular anterior teeth was accepted).
6. No previous history of orthodontic treatment or past history of any major illness or operation.

Birth date was taken from the school register. Body stature was measured in centimeters with the subject standing in normal anatomical position with shoes removed.

Body weight was measured on a standard weighing machine. The weight was measured in kilograms with the patients in light clothes and shoeless. The lateral cephalograms and the right hand-wrist X-rays were obtained on a single 10 × 12 inch film. Before developing, each film was assigned a serial number. By positioning the cassette in the headholder with greater horizontal dimension the craniofacial structures were projected on to an area 10 × 8 inches, the remaining 10 × 4 inches being available for the hand-wrist skeleton.

The cephalogram was taken with teeth in centric occlusion using a vertical counterbalanced cephalostat. The film-tube distance was kept constant at five feet. The cephalometric roentgenogram was exposed first on two thirds of the film by masking the remaining portion with a lead sheet.

Subsequently, the cassette was removed from the headholder and another, bigger, lead sheet was used to cover the previously exposed area. Then the cassette was placed on a stool and the subject's right hand and wrist radiographed at a film-tube distance of 36 inches.

The following facial areas were traced (Fig. 1): orbitoethmoidal, total maxillary and total mandibular.

These areas consisted of points and outlines where growth demarcation seemed reasonable. The boundaries of the orbitoethmoidal area are: a) a plane joining nasion (N) to sella (S); b) a line from the spheno-ethmoidal junction (point E) to the superior and anterior angle of the pterygomaxillary fissure; c) most forward boundary of the orbit as seen on the X-ray; d) from the superior-anterior angle of pterygomaxillary fissure to the inferior border of the orbit.

The total maxillary area is bounded by lines from the a) anterior border of pterygomaxillary fissure around the maxillary tuberosity to encompass any crowns up to the occlusal level; b) by an irregular line drawn along the anterior margin of the facial skeleton from the tip of the central incisor up to the lowest point on the inferior border of the orbit (O); and c) a smooth curve from the tip of the central incisor through the first permanent molar cusp (Occl.).

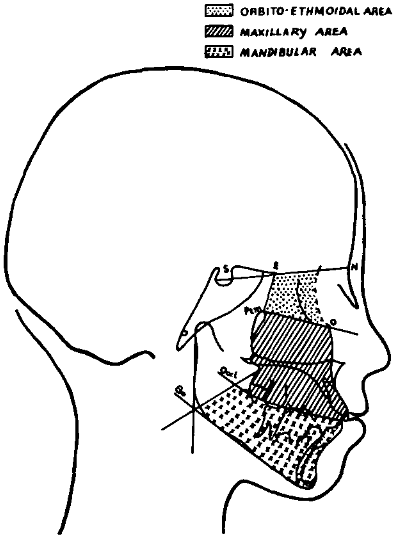

Fig. 1

The total mandibular area is located by a) a straight line from gonial angle (Go) to the intersection of the occlusal curve and b) the remainder of the mandible including the central incisor.

The total surface area of each of these facial areas was measured by a planimeter, a useful and accurate instrument for computation of areas having irregular boundaries. It gives an accuracy within one percent. Each area was measured at least four times until two consecutive readings were identical.

The skeletal age was determined by comparing the carpal films of our subjects with the standard hand and wrist radiographs of specific age levels for girls given by Flory.[7]

The heights and weights were compared with the tables of normal heights and weights for Hindu girls

TABLE I

THE MEAN, STANDARD DEVIATION, STANDARD ERROR AND PERCENTAGE OF STANDARD ERROR OF ALL VARIABLES

No. Variable	*Mean*	*S.D.*	*S.E.*	*% of S.E.*
1. Height age	120.69 months	15.16	2.56	2.12
2. Weight age	118.29	18.17	3.07	2.59
3. Chronological age	132.86	9.02	1.52	1.14
4. Skeletal age	120.29	14.56	2.46	2.04
5. Orbitoethmoid area	6.02 sq. cms	0.76	0.12	2.14
6. Maxillary area	17.17	1.96	0.33	1.93
7. Mandibular area	18.13	1.80	0.30	1.67

for specific age levels. Such standard norms were available from a technical report from the Indian Council of Medical Research.[14] Thus, each subject was assigned four ages, namely, height, weight, skeletal and chronological (Table I).

The data, thus collected, were subjected to standard statistical evaluation methods.

Discussion

From the survey of literature it is evident that this type of investigation had not been carried out elsewhere. Only one direct reference was available in the literature (Rose[18]) where the facial areas were correlated with the height, weight and skeletal ages. But the age range of the subjects studied by Rose was very wide, i.e., 9 to 18 years. Others have correlated height and weight with the skeletal and dental ages, but have not measured the facial areas.[2,11]

It was also observed that there are contradictory views regarding the interrelationship between dentofacial growth and other body measurements. The present study, therefore, is an attempt to probe the above problem in the light of the data collected.

According to Graber[8] the time just before and during puberty is the period of greatest change and is the best for achieving the greatest success in orthodontic treatment. Moreover, it is an established fact that girls are always ahead of boys in their skeletal maturation.[5,15,18] Therefore, the subjects just before the age of puberty, i.e., 120 months to 144 months were studied in this investigation. Since Hindu is a predominant population of a fairly uniform racial status in Gujarat, all the subjects selected for this study were Hindus.

Reports on the use of planimeter are also not common in literature concerning orthodontic research. Rose[18] had used this instrument in 1960, Richardson[17] in 1972 and, recently, Vig and Cohen[21] employed the planimeter to measure the size of the tongue shadow in various mandibular positions.

The method of taking lateral cephalogram and hand-wrist X-rays, both on a single 10 × 12 inch X-ray film, though not very common is not new. This technique was suggested by Grave[10] in 1971. It is useful in hand-wrist X-rays of one side only along with the lateral cephalogram. In the majority of cases the ossification of sesamoid bone in the adductor muscle of the thumb can be shown on the same X-ray as the lateral view of the skull and can be used to predict the facial growth spurt.

ICMR[14] has published standard tables of height and weight for Indian populations. These tables were available either according to their re-

TABLE II

VALUES OF CORRELATION COEFFICIENTS (r) AND TEST OF SIGNIFICANCE (t) FOR ALL AGE VARIABLES

Ages	*Chronological*		*Weight*		*Skeletal*	
	r	t	r	t	r	t
Height	0.5520	3.7998**	0.8105	7.9212**	0.6910	5.4862**
Skeletal	0.4130	2.6025*	0.7077	5.7491**		
Weight	0.6048	4.3589**				

**Significant at 1% level of significance.
*Significant at 5% level of significance.

ligion, i.e., Hindu/Muslim/Jain, etc. or according to their residence, i.e., urban/rural. Hence a problem arose as to which one should be adopted for comparison as there was no separate standard for Hindu girls from urban areas. Since all the girls selected for this study were Hindu and as such no attempt was made to separate them according to their residence, i.e., urban or rural, the standard table based on religion was taken for comparison.

The skeletal ratings in years were converted into months by using a table prepared by Flory.[7] These standards were prepared by Flory by examining a large sample of American girls. Thus it represents an American standard and not the Indian. However, these standards were employed during the present study because of the absence of any such standard published exclusively for Indian, Hindu girls. Gupta and Chawla[12] have provided norms only for shape and sizes of wrist bones at different dentitional levels for North Indian children. Also, the atlas of hand-wrist X-rays prepared by Flory[7] is widely accepted and frequently used.

Height age and weight age in this study show highest correlation (r = 0.8105) Table II. This value is not as high as reported by Green[11] (r = 0.8145). Height and weight ages showed lowest correlations with the chronological age (r = 0.552 and r = 0.6058, respectively); values reported by Green are r = 0.6657 and r = 0.5534, respectively. Height and weight ages in this study are well-related with skeletal age (r = 0.691 and r = 0.7077, respectively). Green's values are higher (r = 0.7859 and r = 0.767).

Chronological age of this study shows significant correlation with skeletal age (r = 0.4143); this value is higher than the one reported by Lauterstein[16] (r = .292) but lower than the value reported by Green (r = 0.6882).

The correlation coefficients between skeletal, chronological, height and weight ages ranged from 0.413 to 0.8105 which showed moderately high association, but not as high as reported by Demisch and Waterman[6] (0.83 to 0.89) and Green (0.46 to 0.81).

Maxillary and mandibular areas as seen in Table III are well-related to to each other (r = 0.6705). Rose also showed a particular close concomit-

TABLE III

TABLE SHOWING VALUES OF CORRELATION COEFFICIENTS (r) AND TEST OF SIGNIFICANCE (t) FOR DIFFERENT FACIAL AREAS

Areas	*Maxillary*		*Mandibular*	
	r	t	r	t
Orbitoethmoidal	–0.03	–0.18	–0.05	–0.30
Mandibular	0.67	5.18**		

**Significant at 1% level of significance.

TABLE IV

TABLE SHOWING VALUES OF CORRELATION COEFFICIENTS (r) AND TEST OF SIGNIFICANCE (t) BETWEEN ALL AGE VARIABLES AND FACIAL AREAS

Areas	*Height age*		*Weight age*		*Chronological age*		*Skeletal age*	
	r	t	r	t	r	t	r	t
Maxillary	0.52	3.50**	0.59	4.22**	0.62	4.58**	0.41	2.64*
Mandibular	0.56	3.89**	0.62	4.64**	0.43	2.74**	0.60	4.33**
Orbitoethmoidal	0.11	0.65	0.09	0.52	−0.08	−0.50	−0.21	−1.26

**Significant at 1% level of significance.
*Significant at 5% level of significance.

ance between them. The orbitoethmoidal area in this investigation, as was expected, did not show any significant correlation with either maxillary or mandibular areas, skeletal, chronological, height, or weight ages. This is because the growth of this area is of the neural type and the growth of the maxillary and mandibular areas fell in the general type of growth pattern. In the neural type pattern 90 percent of the growth is completed by the time the child reaches the age of six years. The remaining growth takes place gradually (Boyd).[3] For this reason, consideration of the orbitoethmoidal area as a typical facial area is most questionable. The mandibular area in the present investigation showed the highest correlation with the weight age (r = 0.6295) and lowest with chronological age (r = 0.431) (Table IV).

Figures 2 and 3 demonstrate regression equations showing the deviation of calculated values from actual values of coefficients of regression. It can be noted from these graphs that the distance of the readings scattered around the regression line indicates the deviation of predicted value from the actual value.

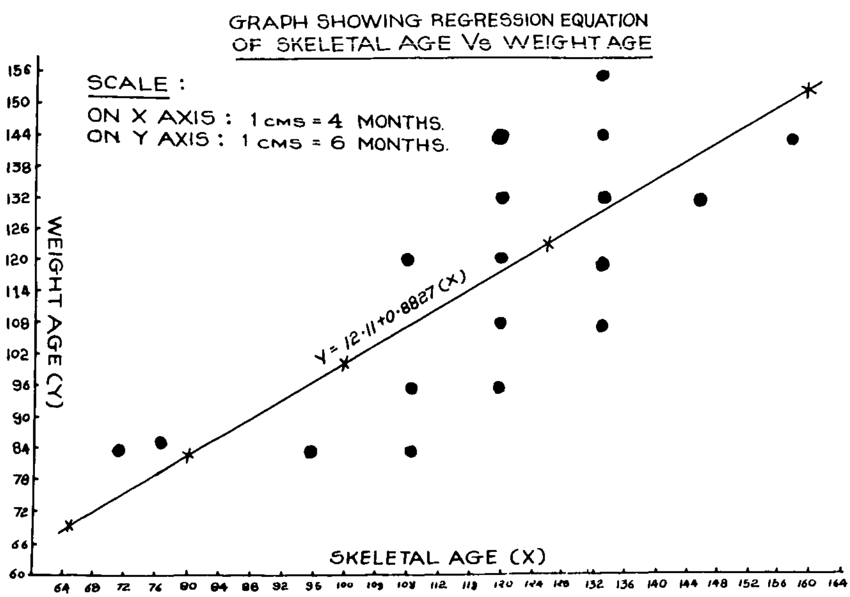

Fig. 2

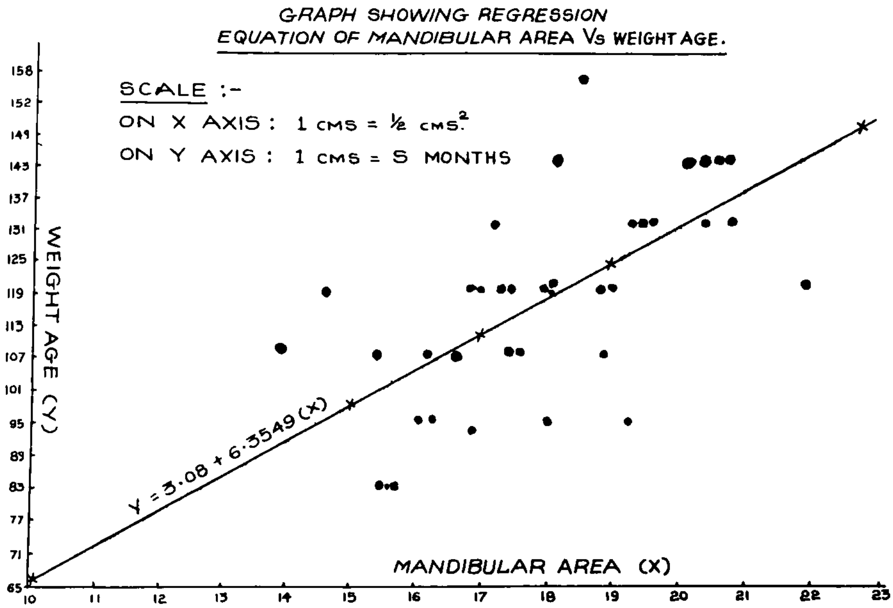

Fig. 3

One point should be stressed that the growth of the facial areas has not been correlated with body growth in previous reports except that of Rose.[18] But the age range of the sample studied by him was very wide, i.e., 9 to 18 years. Green[11] did not measure facial areas and, in addition to this, the sample number and the sex of the subjects also varied. Hence the comparison of findings of this study with those of others has been done on a very general basis.

With this reservation it can be said that the results of this study confirm the findings of the previous workers[1,4,11,18] that chronological age is not a reliable guide of physiological maturity. Though skeletal age of a patient is a more reliable indicator for this purpose, it may be concluded from our findings that height and weight are the most reliable body dimensions of the child's progress toward maturity. This is because height and weight are the two composite human measurements which sum up all increments in growth at that particular age. From that it can be hypothesized that general body growth as demonstrated by stature and body weight does bear some relationship to facial growth.

On the basis of these findings it is possible to express one variable in terms of others. This is done only in those fifteen instances where values of correlation coefficients are significant at the 1% level, i.e., out of 100 cases, it is true in 99 cases and may go wrong only in one case. This level of significance is fairly high to draw the conclusions. The general formula for prediction of one variable (y) from the other (x) is $Y = 3\ a + b\ (x)$. The variables x and y are given in Table V. The values of "a" and "b" were calculated and are also given in Table V.

To be more precise the maximum and minimum values of "b" constant have been calculated (L_1 and L_2 test). Thus L_1 shows the minimum value of "b" and L_2 shows maximum value

TABLE V

TABLE SHOWING 'x' AND 'y' VARIABLES AND CALCULATED 'a' CONSTANT AND 'b' COEFFICIENT OF REGRESSION FOR USING GENERAL FORMULA OF PREDICTION $y = 3a + b(x)$

Sr. No.	x	y	a	b	L_1*	L_2**
1.	Height age	Weight age	1.06	0.971	0.730	1.212
2.	Chronological	Skeletal	31.71	0.666	0.162	1.170
3.	Chronological	Height	−2.52	0.927	0.446	1.407
4.	Chronological	Weight	−43.52	1.217	0.667	1.797
5.	Skeletal	Height	34.2	0.719	0.461	0.976
6.	Skeletal	Weight	12.11	0.882	0.580	1.184
7.	Maxillary area	Mandibular area	7.56	0.615	0.382	0.849
8.	Maxillary	Skeletal age	66.98	3.104	0.790	5.418
9.	Maxillary	Chronological	83.55	2.871	1.639	4.104
10.	Maxillary	Weight	23.97	5.493	2.931	8.053
11.	Maxillary	Height	51.59	4.024	1.761	6.287
12.	Mandibular	Skeletal	31.82	4.879	2.667	7.092
13.	Mandibular	Chronological	93.7	2.160	0.609	3.710
14.	Mandibular	Height	34.95	4.729	2.340	7.117
15.	Mandibular	Weight	3.08	6.354	3.666	9.042

* L_1 = minimum value of 'b' ** L_2 = maximum value of 'b'

of "b" for that particular instance. In short, L_1 and L_2 show the range within which the value of "b" lies.

However, in any biological science there are many variations. Every individual is unique in itself. It is futile to fit an individual in a given framework of standard norms. Rather an attempt should be made to fit such standard norms in an individual with necessary deviations. This concept equally holds true in case of orthodontics as this is a science of infinite variation, where each orthodontic problem is unique.

It is felt that the present study can form a basis for the future longitudinal study of growth pattern of these same subjects in relation to their skeletal development. This study also points out the need for more extensive investigation, the need for more current tables and norms, and the need for a larger sample from both sexes for precise appraisal of growth and development.

Summary and Conclusions

The data from 35 premenarchial Gujarati, Hindu girls, selected at random, in the age range of 120 months to 144 months were collected to find out statistically the nature and the values of correlation coefficients among various facial areas and other body dimensions such as body weight, stature, chronological and skeletal ages.

The correlation coefficients between skeletal, chronological, height and weight ages ranged from 0.413 to 0.8105 showing moderately high association. Height and weight ages turned out to be the most reliable indicators of growth and development of facial areas in this age group and the chronological age as an ineffectual indicator of the same.

Maxillary and mandibular areas showed a high value of correlation coefficients (0.67) while the orbito-ethmoidal area did not show any correlation with any age variables or with other facial areas. The mandibular areas showed the highest correlation with weight age (0.63) and lowest with chronological age (0.431). The maxillary area showed highest correlation with chronological age (0.62) and lowest with skeletal age (0.42).

Fifteen empirical formulae have

been developed by which average value of facial areas could be predicted from the other variables.

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