The Nature of Cranial Vault Variation and Its Relation to Facial Height

M. McKeown, B.D.S., D.Orth., R.C.S.

A. Richardson, M.Sc., B.D.S., D.Orth.

In a series of investigations into the nature of craniofacial form with particular reference to the open bite and deep overbite types of orthodontic problems, the suggestion was made that the shape and size of the endocranium might offer the clinician some clues and pointers to future growth of the face.[12] Early cephalometric growth studies suggested that the facial proportions were determined at an early age and thereafter did not change,[4,5] but subsequent investigations have highlighted the dramatic changes that may occur in facial form during the teenage period.[2,9] That the endocranial outline is complete at an early age is well recognized and, if both facial and endocranial growth are at least partially under genetic control, it is not inconceivable that early-established endocranial parameters might be associated with the final facial configuration. According to Howells,[7] Osborne and DeGeorge,[10] and Hunter,[8] vertical craniofacial parameters show greater evidence of genetic control than do anteroposterior measurements; consequently, studies of face height seemed to offer the best hope of positive results.

The purpose of the present investigation was to probe the strength of the association between the face height and the vertical, lateral and anteroposterior endocranial dimensions.

A second but no less important feature of the investigation was examination of the nature of cranial vault variation.

The question at issue is whether morphological variations in crania adhere to a set pattern or not. There appear to be three possible alternative hypotheses, namely:

1. Crania may exhibit independent variations of major dimensions, e.g., length, height and breadth maxima. These could result in crania of all shapes and sizes.

2. Crania could be divided into certain general groups indicating a specificity of form.[3] Crania with large height dimensions might have small width dimensions and, conversely, skulls with small height dimensions might have large width dimensions. This sort of association is implicit in the terms brachycephalic, dolicocephalic and mesocephalic.

3. Crania might have a general form constancy irrespective of total size or volume, which is the antithesis of the second hypothesis. In other words, skulls which have small height dimensions might also have small breadth dimensions and so on.

It is difficult to summarize the present concepts on this subject as they have never been very precisely defined. Perhaps the general consensus may lie between the first and second possibilities.

Material and Methods

Thirty-two fully-grown dried skulls with sufficient teeth present to register centric occlusion were collected. These skulls were of unknown origin and were used as teaching material in the Department of Anatomy and School of Dentistry in the Queen's University Belfast. The skulls were fixed in an Adams' cephalostat;[1] 90° left lateral and straight posteroanterior views were

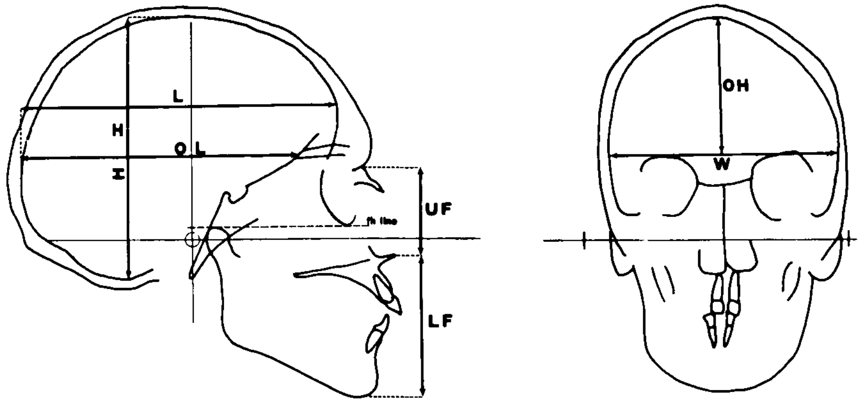

Fig. 1

taken using a target-machine distance of five feet. The skulls remained in a constant position in relation to the earposts for both exposures so that the two films could be coordinated for analyses in three dimensions.

The films were orientated with reference to the Frankfurt plane over a viewer incorporating a metric graph grid. All measurements were taken parallel with or at right angles to this plane. Measurements were recorded as follows (Fig. 1):

Endocranial

Length (L) — Maximum anteroposterior length parallel to the orientation plane.

Height (H) — Maximum height at right angles to the orientation plane.

Width (W) — Maximum width at the level of the supraorbital margins.

Supraorbital level Length (OL) — The maximum length on the lateral view at the level of the supraorbital margins.

Supraorbital vertical Length (OH) — The maximum height measured from the supraorbital level line.

TABLE I
DOUBLE DETERMINATION

	Standard Error of Single Determination (mm.)
Skull Length	1.03
Skull Height	1.23
Skull Breadth	0.75
Sup. Orb. Vert. Ht.	0.75
Inf. Orb. Vert. Ht.	0.99
Upper Face Ht.	0.67
Total Face Ht.	0.52
Lower Face Ht.	1.00
Orbital Level Length	1.30

Facial

Upper Face Height (UF) — The vertical distance from nasion to the anterior nasal spine.

Lower Face Height (LF) — The vertical distance from the anterior nasal spine to menton.

Measurements were taken to the nearest millimetre and were repeated on a second occasion. The standard error of a single determination was calculated according to Dahlberg.[6] The results are shown in Table I. These errors are quite small in relation to the overall size of the measurements and for subsequent calculations the first set of data was used.

Correlation coefficients were then calculated between the various measurements and tested for statistical sig-

TABLE II
CORRELATION COEFFICIENTS FOR ENDOCRANIAL VAULT MEASUREMENTS

	Length (L)	Height (H)	Width (W)
Length (L)		+0.56xxx	+0.30
Height (H)	+0.56xxx		+0.62xxx
Width (W)	+0.30	+0.62xxx	

xxx Indicates significance $P<.001$

nificance. The results are shown in Tables II, III and IV.

DISCUSSION

The high positive correlations between endocranial length and height, and between height and width, support the concept of general form constancy (Table II). If these measurements had varied independently, as in our first hypothesis, the correlation coefficients would have been nonsignificant; if these measurements had been inversely related, as in the second hypothesis, the coefficients would have been significant but negative. The results in this investigation support the hypothesis that, while endocrania may vary in size, the general shape and form is maintained so that if the width is large the height will also be large, and so on.

As for the relationship between facial and endocranial measurements (Tables III and IV), the results are variable. There is a moderately strong association between upper face height and endocranial width and length, and a weaker association between upper face height and orbital level length. The only significant association between lower face height and the endocranial parameters tested in this investigation is orbital level length.

Prognostication of the final upper face height would be useful to the orthodontic clinician and, if the three significant correlations demonstrated here were included in a multiple regression analysis together with other endocranial measurements which may be associated with upper face height, it

TABLE III
CORRELATION COEFFICIENTS BETWEEN ENDOCRANIAL VAULT MEASUREMENTS AND UPPER FACE HEIGHT

	Upper Face Height
Skull Length	+0.46xx
Skull Height	+0.21
Skull Width	+0.46xx
Supraorbital Height	+0.21
Orbital Level Length	+0.42x

x Indicates significance $P<.05$
xx Indicates significance $P<.01$

TABLE IV
CORRELATION COEFFICIENTS BETWEEN ENDOCRANIAL VAULT MEASUREMENTS AND LOWER FACE HEIGHT

	Lower Face Height
Skull Length	+0.19
Skull Height	+0.18
Skull Width	+0.11
Supraorbital Height	—0.17
Orbital Level Length	+0.38x

x Indicates significance $P<.05$

might be possible to make a good estimate of final upper face height simply by measuring the endocranium at, say 7-10 years. It has been shown previously that in open-bite cases seen at 7-10 years, there is a delay in upper facial growth.[11] If it proves possible on the basis of endocranial measurements to predict upper face height, we could then sort out the cases that are likely to improve spontaneously from those that are not.

The weaker association between lower face height and the endocranium will come as no surprise since it has long been suspected that the adaptive dentoalveolar skeleton is more susceptible to environmental influences than other parts of the face. Indeed, the results of this investigation are very much in line with those of Hunter,[8] who found lower F ratios in the dental area than elsewhere in like-sexed twins.

Nevertheless, associations between the facial area and the endocranium seem to exist and provide a stimulus to further investigation, which may lead us to a greater awareness of the nature of the craniofacial complex and the prognostication of final facial shape and size.

School of Dentistry,
Queen's University,
Belfast, Northern Ireland

REFERENCES

1. Adams, C. P. and Brown, W. A. B. The Adams cephalostat. *Europ. Orth. Soc. Trans.* 1966.
2. Björk, A. The face in profile. *Svensk Tandläkere-Tidschrift* 40, No. 5B (suppl.) 1947.
3. Brash, J. C. *The Growth of the Jaws Normal and Abnormal in Health and Disease.* Dental Board of the United Kingdom, 1924.
4. Broadbent, B. H. The face of the normal child. *Angle Orth.* 7:183-207, 1937.
5. Brodie, A. G. On the growth pattern of the human head from the third month to the eighth year of life. *Amer. J. Anat.* 68:209-292, 1941.
6. Dahlberg, G. *Statistical Methods for Medical and Biological Students.* Allen & Unwin Ltd., London, 1948.
7. Howells, W. W. Body measurements in the light of familial influences. *Am. J. Phys. Anth.* 7:101-108, 1949.
8. Hunter, W. Stewart. A study of the inheritance of craniofacial characteristics as seen in lateral cephalograms of 72 like-sexed twins. *Europ. Orth. Soc. Trans.*, 1965.
9. Lande, M. S. Growth behavior of the human bony facial profile as revealed by serial cephalometric roentgenology. *Angle Orth.* 22:78-90, 1952.
10. Osborne, E. R. H. and DeGeorge, F. V. *Genetic Basis of Morphological Variation.* Harvard University Press, 1959.
11. Richardson, A. A cephalometric investigation of skeletal factors in anterior open bite and deep overbite. *Europ. Orth. Soc. Trans.* pp. 159-171, 1967.
12. ————. Skeletal factors in anterior open bite and deep overbite. *Am. J. Ortho.* 56:114-127, 1969.