A Study of Craniofacial Form

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Dolichocephaly and brachycephaly comprise the two basic extremes of skull form: the former is associated with a relatively narrow and horizontally long cranium while the latter has a short, broad and more rounded form. The cranial base is flat and long in dolichocephalics, so that the flexure between the middle and anterior cranial floor is more open than that in brachycephalics. As a result, the whole maxillary complex tends to be protrusive relative to the mandible and is lowered relative to the mandibular condyle leading to the downward and backward rotation of the entire mandible. Due to such a forward maxillary location and backward placement of the mandibular body, dolichocephalics exhibit a tendency for mandibular retrusion and an Angle Class II molar relationship. The craniofacial profile therefore tends to be retrognathic in dolichocephalics.

As a consequence of the wide, round skull form of brachycephalics, the cranial base is more upright with a relatively closed flexure, thereby decreasing the horizontal dimensions of the middle cranial fossa. Consequently, brachycephalics tend toward relative nasomaxillary retrusion and forward mandibular placement. This leads to an Angle Class III molar relationship with a prognathic craniofacial profile.

Skull morphogenesis and growth, however, are complex particularly regarding brachycephaly and dolichocephaly. Disproportionate growth, for instance, occurs between the cerebral and cerebellar hemispheres and the ventral brain axis and directly influences growth in the skull roof and cranial base, respectively.[1] The simultaneous development of the brain, cranial base flexion and erect posture influences the location of the craniofacial complex.[2,3] Craniofacial morphology is also affected by the surrounding functional matrix.[4-7] Indeed, a relationship exists between craniofacial morphology and the degree of electromyographic muscular activity,[8] bite force,[9] adenoidal obstruction[10] and head posture.[11] Dentoalveolar morphology is also associated with tongue and lip function.[12] Moreover, the craniofacial complex is capable of compensatory changes which may to a certain extent mask some craniofacial anomalies, defects or deficiencies.[13,14] Until there is more information regarding brachycephaly and dolichocephaly, however, the factors influencing the development of these two extremes of skull form will remain obscure.

This study was undertaken to enquire into the detailed contrasts in the craniofacial skeleton of dolichocephalics and brachycephalics. Thus it was hoped to ascertain whether the contrasts were confined to the craniofacial skeleton or also embraced the teeth and dental arches.

Materials and Methods

This study was based upon a comparison of the craniofacial profiles, dental arches, and teeth of 50 male dolichocephalics and 50 male brachycephalics. The subjects were all Caucasoids and equally matched for age in the range 18-25 years. Dolichocephalics were defined as subjects with a cephalic index less than 75 (anthropologic skull breadth expressed as an index of skull length), and brachycephalics with an index greater than 80. In addition, the subjects were selected with complete permanent dentitions (excluding third molars), no history of orthodontic treatment, no excessive loss of tooth substance due to caries or attrition, and of the same socioeconomic group.

Alginate-base hydrocolloid casts were taken from each maxillary and mandib-

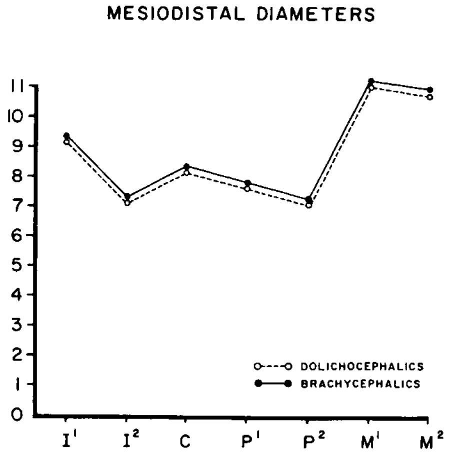

Fig. 1 Mean mesiodistal crown diameters of maxillary permanent teeth of brachycephalics and dolichocephalics.

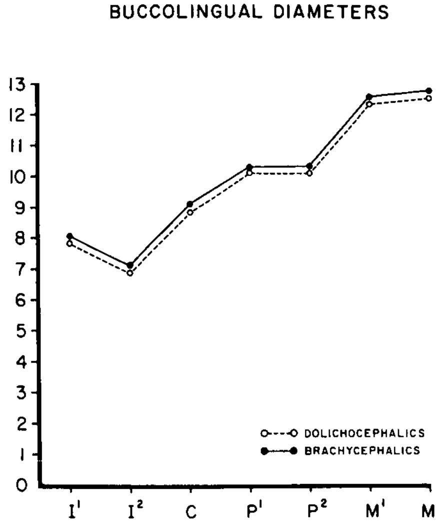

Fig. 2 Mean buccolingual crown diameters of maxillary teeth of brachycephalics and dolichocephalics.

ular arch. From these casts, dental arch and tooth dimensions were measured using dial calipers reading to the nearest 0.1 mm. The mesiodistal and buccolingual crown diameters[15] were averaged for the teeth of both sides of each dental arch. In addition, dental arch widths between the centers of corresponding teeth on each side of the arch and oblique lengths between the most mesial aspect of anterior teeth and the most distal aspect of posterior teeth were measured for each arch, as previously described by Lavelle.[16]

The craniofacial profiles of the two groups of subjects were defined from lateral cephalographs taken under standardized conditions using a cephalostat. Following the definitions and techniques of Walker and Kowalski,[17] 177 datum points were identified for each craniofacial profile. Subsequently the cartesian coordinates for the datum points were derived with a strip-chart digitizer. The coordinates of each datum point were then transformed to standardized coordinates based on a common set of axes. These axes were predefined by a point of origin and a directional point common to all the cephalographs. The axes for each cephalograph were shifted to the point of origin and rotated around it so the positive direction of the X axis passed through the directional point.[18] In this manner the coordinates of the cephalographs included in this study were comparable one with another.

In addition to univariate analyses the tooth and dental arch dimensions and craniofacial coordinates of the two samples were analyzed by computing multiple correlation coefficients, canonical correlation coefficients, and canonical analysis of discriminance.[16] This latter technique was employed to maximize the discrimination between brachycephalics and dolichocephalics.

Results

The mesiodistal crown diameters were all consistently greater in brachycephalics than dolichocephalics (Fig. 1) and also for the buccolingual crown diameters (Fig. 2). Generally, these contrasts were not significant at the 2% confidence limits. Similarly, multiple correlation coefficients between the mesiodistal and buccolingual diameters of one tooth and those of the remaining

TABLE I
Multiple correlations between teeth and remaining teeth.

Maxillary	Dolicho-cephalics Coefficient	Brachy-cephalics Coefficient
I^1	0.62 ± 0.32	0.60 ± 0.39
I^2	0.70 ± 0.38	0.64 ± 0.44
C	0.54 ± 0.51	0.52 ± 0.46
P^1	0.75 ± 0.33	0.65 ± 0.38
P^2	0.76 ± 0.35	0.71 ± 0.41
M^1	0.68 ± 0.39	0.62 ± 0.44
M^2	0.64 ± 0.44	0.60 ± 0.48
Mandibular		
I_1	0.67 ± 0.27	0.63 ± 0.32
I_2	0.78 ± 0.24	0.74 ± 0.27
C	0.74 ± 0.38	0.70 ± 0.41
P_1	0.75 ± 0.29	0.69 ± 0.37
P_2	0.72 ± 0.31	0.69 ± 0.34
M_1	0.69 ± 0.36	0.64 ± 0.39
M_2	0.68 ± 0.29	0.63 ± 0.33

teeth of the dental arch were greater in dolichocephalics than brachycephalics (Table I). Furthermore, this was confirmed from canonical correlations between all the crown diameters of both dental arches combined together, which was 0.88 for brachycephalics and 0.92 for dolichocephalics. Generally therefore, the tooth dimensions were slightly more correlated in dolichocephalic than brachycephalic skulls.

TABLE II
Multiple correlations between arch dimensions and remaining arch dimensions.

Maxillary	Dolicho-cephalics Coefficient	Brachy-cephalics Coefficient
I^1-I^1	0.49 ± 0.35	0.47 ± 0.40
C-C	0.63 ± 0.47	0.54 ± 0.39
M^1-M^1	0.67 ± 0.37	0.59 ± 0.48
I^1-C	0.51 ± 0.40	0.44 ± 0.39
C-M^1	0.59 ± 0.38	4.48 ± 0.36
Mandibular		
I_1-I_1	0.45 ± 0.40	0.36 ± 0.29
C-C	0.58 ± 0.52	0.52 ± 0.38
M_1-M_1	0.62 ± 0.49	0.59 ± 0.52
I_1-C	0.53 ± 0.45	0.50 ± 0.43
C-M_1	0.52 ± 0.43	0.46 ± 0.40

The dimensions of arch width were all greater in brachycephalics than dolichocephalics with the reverse relationship pertaining to dental arch lengths (Fig. 3); these contrasts were not statistically significant at the 2% confidence limits. Nevertheless, as shown in Table II, multiple correlation coefficients between one dimension and the remaining arch dimensions were all greater in dolichocephalics than brachycephalics. Also the canonical correlation coefficients between all the arch dimensions were 0.84 for dolichocephalics and 0.81

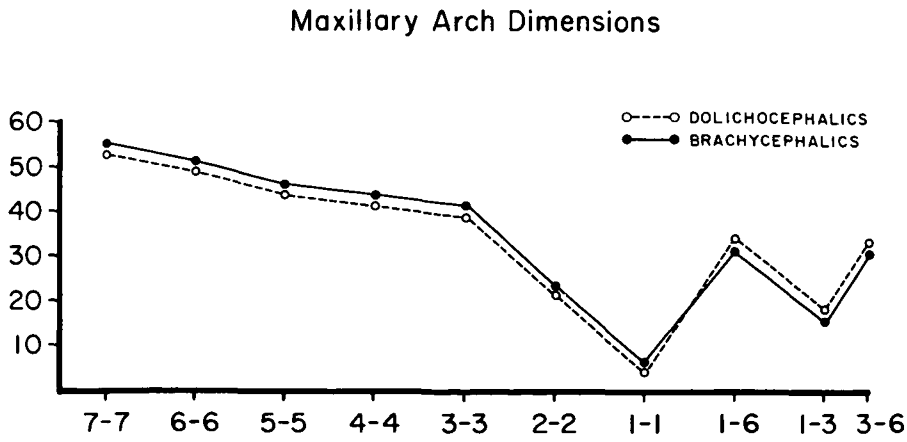

Fig. 3 Mean length and width maxillary arch dimensions of brachycephalics and dolichocephalics.

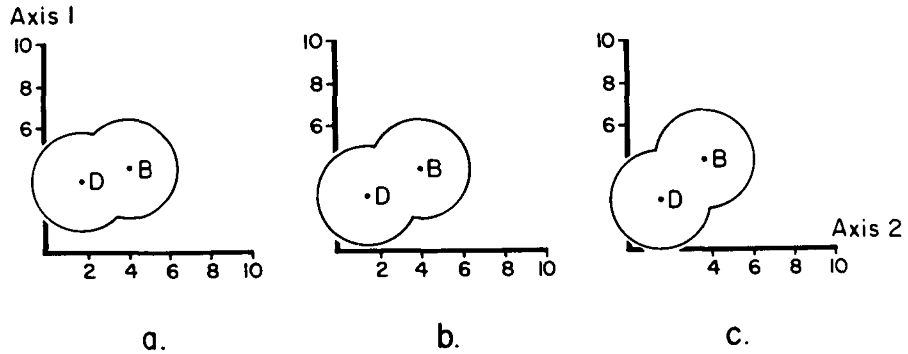

Fig. 4 Centroids (means) and 95% confidence limits of brachycephalic (B) and dolichocephalic (D) tooth dimensions. a = maxillary and mandibular tooth dimensions; b = maxillary tooth dimensions; c = mandibular tooth dimensions.

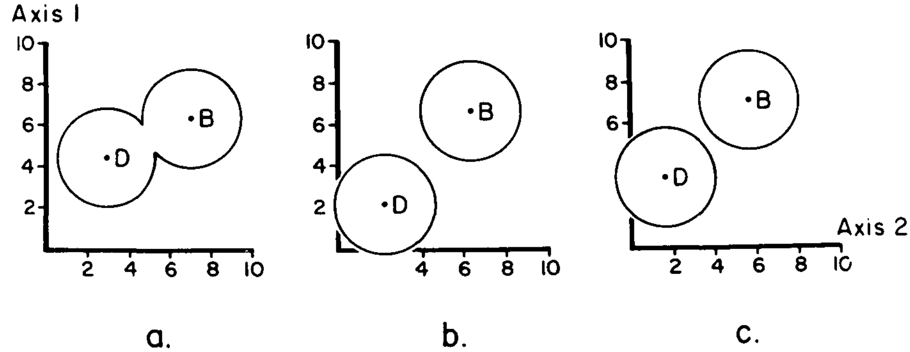

Fig. 5 Centroids and 95% confidence limits of brachycephalic (B) and dolichocephalic (D) arch dimensions. a = maxillary and mandibular arch dimensions; b = maxillary arch dimensions; c = mandibular arch dimensions.

for brachycephalics. The arch dimensions were therefore more closely correlated in dolichocephalics than brachycephalics.

When all the crown diameters were subjected to canonical discriminant analysis, there was no significant separation between brachycephalics and dolichocephalics (Fig. 4). By contrast, there was significant separation on canonical analysis of all the maxillary or mandibular arch dimensions between these two groups, although such distinctions were masked on comparison of either the maxillary or mandibular arch dimensions combined together (Fig. 5). There was, however, significant discrimination between brachycephalics and dolichocephalics on analysis of all the maxillary and mandibular arch and tooth dimensions combined (Fig. 6).

Univariate analysis of individual craniofacial dimensions showed that the cranial base was longer in dolichocephalics than brachycephalics with the reverse relationship pertaining to the mandible. As illustrated in Table III, the facial dimensions appeared to be more highly correlated one with another in dolichocephalics than brachycephalics. This was confirmed by the canonical correlation coefficients, computed between all pairs of datum points included in this study, with values of 0.74 being derived for dolichocephalics and 0.71 for brachycephalics. Thus the craniofacial skeleton appeared to be

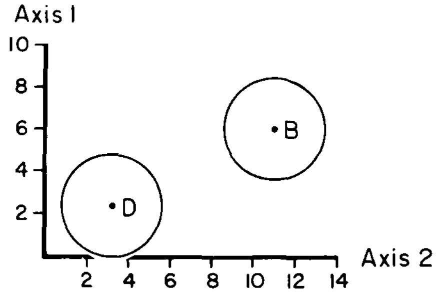

Fig. 6 Centroids and 95% confidence limits of brachycephalic (B) and dolichocephalic (D) maxillary and mandibular tooth and arch dimensions.

more highly correlated in dolichocephalics than brachycephalics.

Canonical analysis of the coordinates for both the whole craniofacial (Fig. 7) and neurocranial (Fig. 8) skeletons showed a significant discrimination between brachycephalics and dolichocephalics. When examining the facial skeleton, however, the separation between dolichocephalics and brachycephalics was greater when the lower rather than upper facial skeleton datum points were analysed (Fig. 9). Thus there are contrasts between the craniofacial and facial skeletons of brachycephalics and dolichocephalics, although the actual differences depend upon the group of dimensions included in the analysis. Generally, discrimination between brachycephalics and dolichocephalics hinged predominantly on the morphology of the cranial base.

TABLE III
Multiple correlations between one facial skeletal dimension and remaining dimensions.

	Dolichocephalics Multiple Correlation	Brachycephalics Multiple Correlation
Palatal length	0.49 ± 0.37	0.44 ± 0.32
Anterior facial height	0.44 ± 0.41	0.41 ± 0.34
Overall mandibular length	0.51 ± 0.43	0.47 ± 0.33
Height of Ascending ramus	0.43 ± 0.46	0.39 ± 0.29

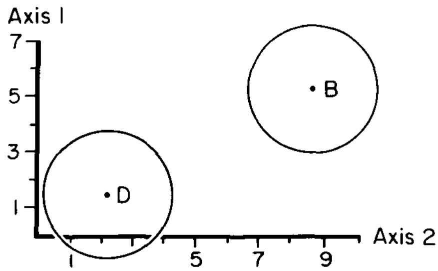

Fig. 7 Centroids and 95% confidence limits of brachycephalics (B) and dolichocephalics (D) based upon analysis of all the craniofacial coordinates combined.

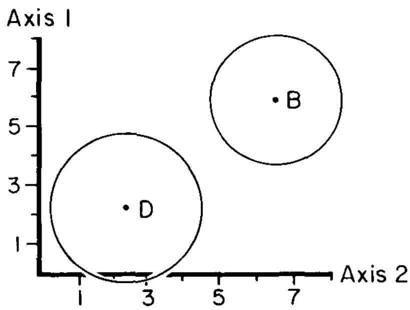

Fig. 8 Centroids and 95% confidence limits of brachycephalics (B) and dolichocephalics (D) based upon analysis of all the neurocranial coordinates combined.

Discussion

The prediction of growth changes ultimately depends upon the quantification of genetic and environmental factors influencing craniofacial morphogenesis.[19] Genetic factors certainly influence craniofacial form[20-23] and recent studies have indicated that the detailed genetic control of bone form is far more complex than is traditionally accepted.[24] Brodie,[25] however, considered that the facial pattern is genetically predetermined with environmental influences only secondary in nature. From a study of twins, however, the anteroposterior dimensions of the face appeared to reflect the effects of envi-

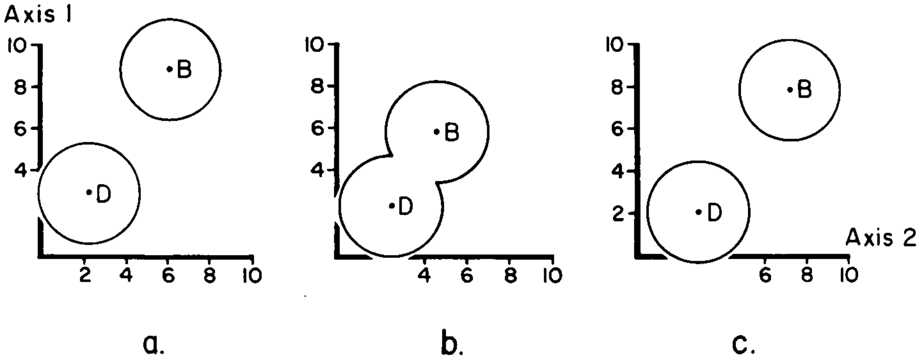

Fig. 9 Centroids and 95% confidence limits of brachycephalics (B) and dolichocephalics (D) based upon analysis of the facial skeleton coordinates. a = whole facial skeleton; b = upper facial skeleton; c = lower facial skeleton.

ronmental influences to a greater extent than do height dimensions,[26] i.e., environment exerts a varying effect on craniofacial form. Van der Klaaw considered the craniofacial complex to comprise at least 30 relatively independent functional units, each governed by its own growth director. This concept was later developed in the functional matrix theory[27] which places the primary importance upon the adaptability of structure to functional patterns and intrinsic environmental conditions. This may be extrapolated by stating that the external configuration of a bone is largely dependent upon a "composite of its functions" with remodelling and relocation allowing function to continue uninterrupted through the normal process of growth and development.[28] This implies that the functional matrix may be the feature that is affected by environmental and genetic factors with bone morphology playing a passive adaptive role. However, intrinsic genetic factors and local epigenetic factors possibly play variable roles in the differentiation of specific areas of the craniofacial complex.[29] Consequently, various areas of the craniofacial complex may be subject to different degrees of genetic and environmental influence during morphogenesis. Thus it is not possible at present to ascertain with any degree of certainty whether the two extremes of skull form, brachycephaly and dolichocephaly, primarily reflect environmental or genetic factors.

Furthermore, the work of Solow[30] has identified the degree of association between one craniofacial region and another. Other workers have noted associations between craniofacial and tooth dimensions[31] and stature.[32] There is also a relationship between the arrangement of tooth roots, dental arch, and skull form.[33] Consequently, the craniofacial complex must be considered as a biological entity rather than a group of discrete but interrelated units.

In this study the teeth, dental arch, and craniofacial dimensions were noted to be more highly correlated in dolichocephalics than brachycephalics. Thus, although tending to be retrognathic in profile, dolichocephalic craniofacial skeletons appear to be more highly integrated biological entities than the prognathic brachycephalics. More data are, however, required before such contrasts may be assigned to genetic or environmental factors. Also caution must be applied when interpreting cephalometric analyses in view of the variations in craniofacial morphology between patients with different Angle's occlusal categories[34] and the late growth changes in the face.[35] Even in the adults with normal occlusion, there may be considerable variability in the craniofacial complex.[36] Until the various factors influencing craniofacial morphogenesis have been identified, prediction of future growth changes will remain, to a certain extent, subjective.

Summary

There are differences in the craniofacial skeleton, dental arch, and tooth dimensions between brachycephalics and dolichocephalics. Furthermore, the craniofacial complex appears to be more integrated biologically in dolichocephalics than brachycephalics.

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