A Cephalometric Study

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Despite many decades of advancement in orthodontic treatment methods, the dynamics of craniofacial change induced by intrinsic mechanisms, e.g., genetic factors, or extrinsic mechanisms, e.g., long-term effect of appliances, are still poorly understood. Yet, if information contained in cephalographs can be analyzed and interpreted in biologic terms, improved insight may be achieved into craniofacial growth and development.

The evaluation of lateral cephalographs comprises an integral component of orthodontic assessment.[1,2] Assessment of the craniofacial skeleton is frequently compromised by the variability existing both between and within individuals. Furthermore, the craniofacial skeleton can never be assumed to be in a "steady state" with changes occurring during adolescence and old age. The variability of the craniofacial skeleton is also compounded by the multiplicity of its component structures,[3] and each component may be subject to varying degrees of genetic and environmental influence.[4] Yet as the etiology of most malocclusions is traceable to subtle intercorrelations of the craniofacial components during growth, objective study of the craniofacial skeleton is crucial for orthodontic diagnosis and assessment.

Measurements and combinations of measurements comprise the traditional techniques for craniofacial assessment.[5-7] Some techniques stress particular relationships for treatment planning criteria[7] whereas others are used to evaluate and predict the direction of facial growth changes.[8] Such techniques provide little insight into the understanding of how and why certain growth patterns develop; they also yield meager information on craniofacial variability. Most traditional techniques are based upon established norms statistically derived from population samples. Nevertheless, more detailed information is required to identify which craniofacial components are more variable than others and only by this means will objective orthodontic assessment be advanced.

This study was undertaken to evaluate the variability of the craniofacial skeleton from Angle's four categories of occlusion. Although based upon subjects within a common age range, this was essentially a pilot study into a method to achieve a more critical metrical definition of the craniofacial skeleton.

Material and Methods

A total of 200 male British Caucasoids, age 10-12 years, was included in this study comprising equal samples from each of the four major Angle occlusal categories, using the method described by Beresford, i.e., Classes I, II Division 1, II Division 2 and III.[9] In addition, the skeletal categories were assessed according to the method outlined by Ballard[10] into skeletal Classes I, II and III. To simplify this study, the subjects were selected so that the categories of occlusion coincided with the skeletal categories, that is, Angle Class I with skeletal Class I, Angle Class II with skeletal Class II, and Angle Class III with skeletal Class III. No subject had received orthodontic therapy.

Lateral skull cephalographs were taken for each subject in an identical standard manner using a cephalostat. Using the definitions previously described by Cleall and Chebib,[11] 33 datum points were defined for each ceph-

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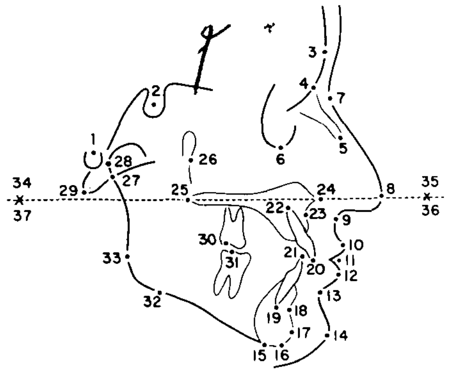

Fig. 1 Datum points defining the facial skeleton, based upon lateral cephalographs.

alograph (Fig. 1). Subsequently, the "x" and "y" coordinates were recorded for each cephalograph in a set sequence using a strip-chart digitizer and the output recorded on punch cards. Since the cephalographs, despite precautions, were taken at varying orientations and elevations, they were transformed to a standard orientation using the technique described by Cleall and Chebib. This entailed the transformation of the datum points of each individual's cephalograph 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 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. The standardized coordinates in each cephalograph were subsequently subjected to analysis.

Using a technique previously described,[12] this study was based upon the multivariate analysis of the standardized cephalographic coordinates derived from Angle's four categories of occlusion. Canonical analysis was the statistical technique selected to maximize the separation between the four occlusal categories and to identify which coordinate or group of coordinates contributed most to the separation between these categories. Six analyses were performed between the four occlusal categories using: (a) coordinates (1-33); (b) coordinates defining maxillary jaw (20, 22, 24-26, 30); (c) coordinates defining mandibular jaw (15-19, 21-28, 31-33); (d) coordinates defining maxillary arches (20, 22, 23, 30); (e) coordinates defining mandibular arches (18, 19, 21, 31) and (f) coordinates defining the soft tissues (7-14).

The results of the analyses were examined by the standard method of plotting the position of the four occlusal categories in relation to pairs of canonical axes. Inspection of the data showed that in each analysis only the first two canonical axes effected appreciable discrimination. Consequently, the central point (centroid) for each occlusal category was plotted for the first two canonical axes, and this was circumscribed by a circle of radius 2.15 standard deviation units thus including 90 percent of individuals. For clarity and simplicity this procedure was adapted for the various occlusal categories included in the present study.

Results

When all the coordinates of each cephalograph were included in the analysis, significant discrimination appeared between each of the four occlusal categories (Fig. 2, Table I). There was little separation between Class II, Division 1 and Class II, Division 2 individuals, but marked discrimination between Class I, II and III individuals. Furthermore, the first canonical axis discriminated Class II, Division 1 from Class II, Division 2 and Class I from III individuals whereas the second canonical axis discriminated Class I and III from Class II individuals. Although with varying degrees of separation between the occlusal categories,

TABLE I

Coordinates of Angle's Class I, II and III subjects for the two canonical axes based upon the analysis of varying numbers of craniofacial dimensions

	Class I		Class II, 1		Class II, 2		Class III	
All dimensions	21.3	14.1	13.2	5.9	8.6	6.0	5.9	14.2
Jaws—								
maxillary/mandibular jaws	18.2	9.8	15.1	2.7	12.2	2.2	9.3	8.6
maxillary jaws	18.6	5.8	15.8	2.0	13.7	2.2	10.9	8.4
maxillary jaw	18.7	7.2	17.9	3.4	15.4	4.6	13.2	8.6
Arches—								
maxillary/mandibular arches	19.6	10.0	15.8	5.0	13.2	4.8	11.4	9.6
maxillary arch	16.5	7.4	16.2	1.6	12.2	1.5	9.4	6.9
mandibular arch	16.2	7.0	12.8	2.8	9.5	2.9	6.3	7.4
Soft tissues	18.0	9.2	17.6	5.3	15.4	5.2	14.7	8.6

All coordinates in standard deviation units

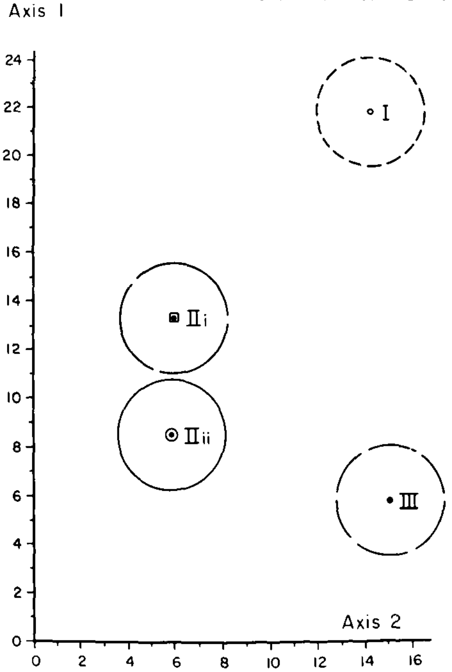

Fig. 2 Centroids and 90% confidence limits for the first two axes, based upon analysis of all the coordinates of the facial skeleton. I = Class I; II, 1 = Class II division 1; II, 2 = Class II division 2 and III = Class III.

this pattern of discrimination was repeated in each of the analyses performed in this study.

For instance, analysis of the coordinates defining the maxillary and mandibulary jaws did not discriminate between the two class II categories but revealed marked separation between Class

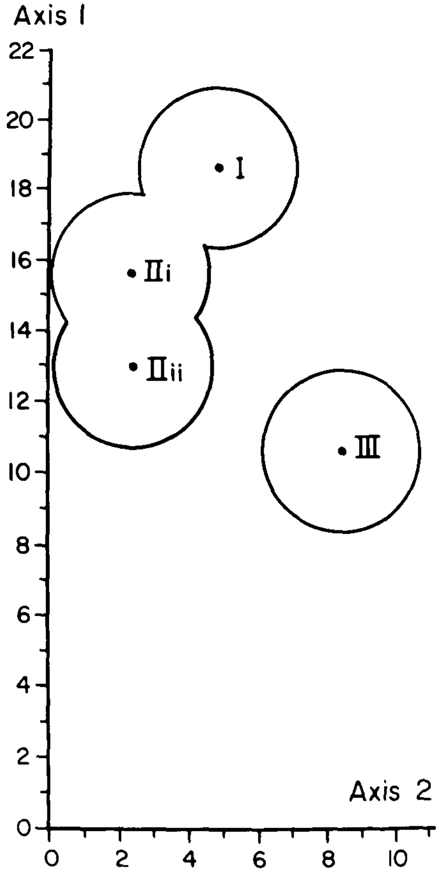

Fig. 3 Centroids and 90% confidence limits for the first two axes, based upon analysis of maxillary jaw coordinates.

I and Class III individuals. Analysis of the maxillary (Fig. 3) and mandibular (Fig. 4) coordinates did not discrimi-

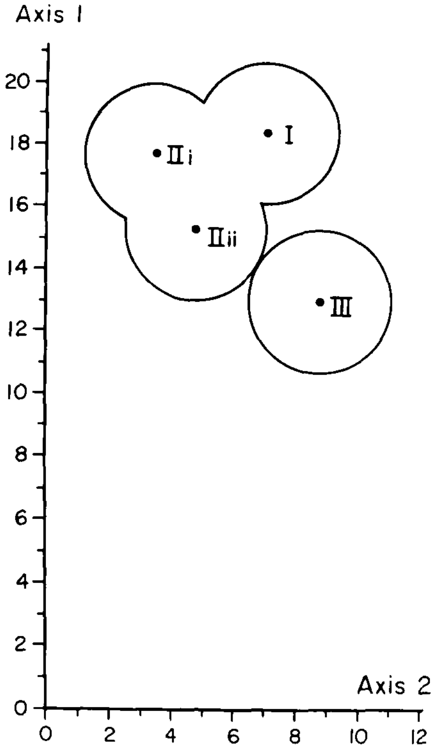

Fig. 4 Centroids and 90% confidence limits for the first two axes, based upon analysis of mandibular jaw coordinates.

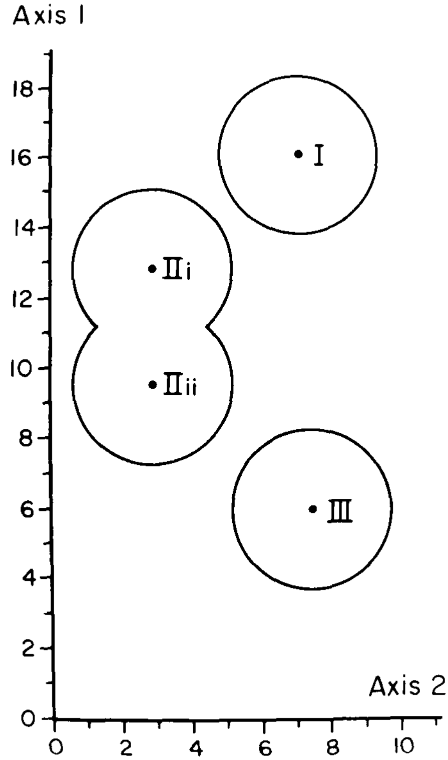

Fig. 5 Centroids and 90% confidence limits for the first two axes, based upon analysis of the mandibular arch coordinates.

nate significantly between Class II and Class I occlusal types. Furthermore, these data suggested that the differentiation between Classes I, II and III was more intimately associated with the maxillary than mandibular jaw dimensions.

By contrast, analysis of the dental arch coordinates showed a slightly greater degree of discrimination between Class I and III from analysis of the mandibular arch coordinates (Fig. 5) compared with analysis of the maxillary (Fig. 6) or maxillary and mandibular arch coordinates. This therefore suggested that the mandibular arch dimensions contributed most to the discrimination between the occlusal categories.

Finally, analysis of the soft tissue coordinates (Fig. 7) showed no significant discrimination between the four occlusal categories. This information suggested that soft tissue parameters are unreliable for the discrimination between the four types.

These patterns of discrimination between the four categories in the various analyses were confirmed from the generalized distance (D^2) statistic (Table II) which provided an indication, in terms of standard deviation units, of the degree of separation between the means (centroids) of the various categories.

An eigen value analysis was superimposed upon each canonical analysis performed in this study to identify which coordinate or group of coordinates contributed most to the discrimi-

TABLE II

Squared generalized distances (D^2) between centroids (means) of Angle's categories based upon analysis of varying numbers of craniofacial dimensions

Dimensions analysed	Generalized distances between Angle's categories			
	Class I-II, 1	Class I-II, 2	Class I-III	Class II, 1-II, 2
All dimensions	6.8	9.2	9.3	2.9
Jaws—				
maxillary/mandibular jaws	5.1	6.5	5.7	2.4
maxillary jaw	2.6	4.1	5.8	1.8
mandibular jaw	2.4	2.5	3.9	1.9
Arches—				
maxillary/mandibular arches	4.0	5.3	5.4	1.6
maxillary arch	4.2	5.0	4.9	2.5
mandibular arch	4.0	5.9	7.8	2.6
Soft tissues	2.8	3.4	3.5	1.4

All generalized distances in standard deviation units

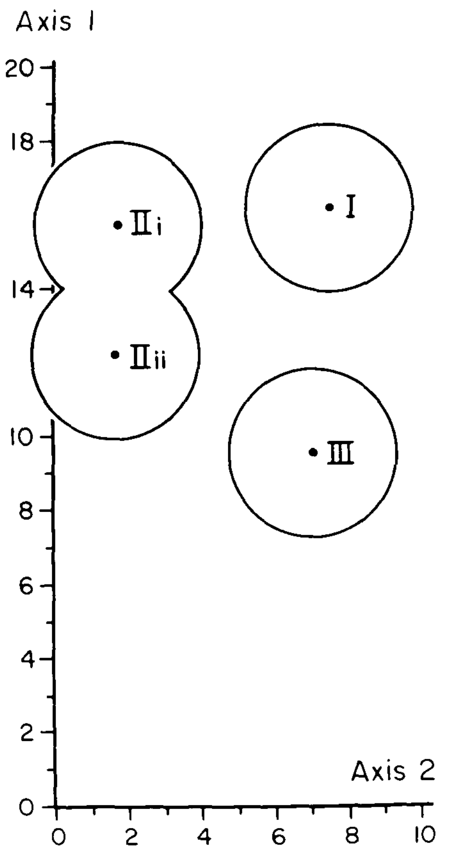

Fig. 6 Centroids and 90% confidence limits for the first two axes, based upon analysis of maxillary and coordinates.

nation between the various occlusal categories. In this study the eigen values indicated that the maxillary jaw and mandibular dental arch coordinates contributed most to the discrimination.

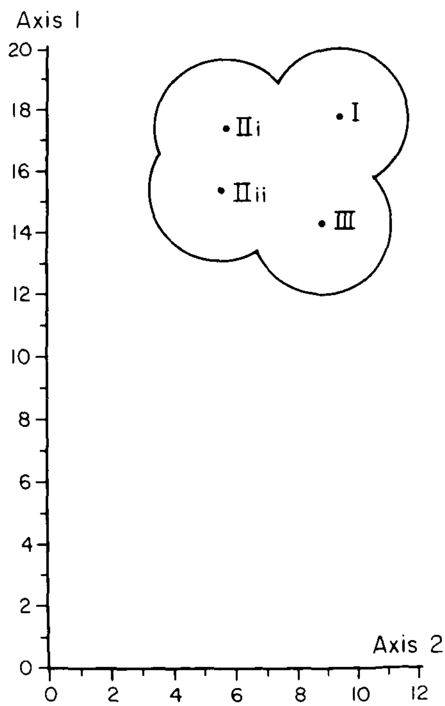

Fig. 7 Centroids and 90% confidence limits for the first two axes, based upon analysis of the soft tissue coordinates.

Discussion

The present study showed a similar pattern of contrast between the four occlusal categories, although the actual degrees of discrimination depended upon which dimensions (coordinates) were included in the analysis. In this study only limited numbers of coordinates were used to define the craniofacial skeleton, which contrasts with the more accurate metrical definition provided by Walker.[13] It is conceivable, therefore, that different patterns and degrees of discrimination between the four classes might have emerged if different or more accurate metrical definitions of the craniofacial skeleton had been analyzed. Also, even with standardization of the craniofacial coordinates to a common orientation, errors in X-ray cephalometry[14] and identification of datum points[15] may have affected the patterns of discrimination identified in this study. Finally, in view of the degree of association between the components of the craniofacial skeleton,[16] it is difficult to identify accurately, even with multivariate analysis, whether some craniofacial components are more dependent on others and vice versa, particularly as some of the coordinates were used to describe more than one craniofacial region.

This study was based upon limited samples of males in Angle's four occlusal categories. Recently, increasing concern for this system of categorization has been voiced in the literature[17] since no longer may they be considered discrete entities. It is conceivable that, if another system of categorization of the subjects included in this study was established, the craniofacial skeleton might possibly have shown a different pattern of discrimination. Nevertheless, multivariate analysis enables the craniofacial skeleton to be examined as a biological entity which contrasts with traditional univariate statistic analyses which enable only one or two dimensions to be considered at any one time.[18]

Finally, the inherent variability of the craniofacial skeleton[19] and soft tissue profile[20] is well-documented. Indeed, the craniofacial skeleton exhibits not only varying degrees of asymmetry[21] but also variation between different ethnic groups[22] in addition to growth changes.[23] Caution must always be applied when interpreting contrasts between craniofacial skeleton. Nevertheless, this study emphasized that even when based upon a meager metrical description of the craniofacial skeleton, multivariate analysis is capable of indicating specific regions more subject to variability compared with others.

Summary

Multivariate analysis of the craniofacial skeleton from subjects with Angle's four occlusal categories showed a similar pattern but with varying degrees of separation depending upon which parameters were included in the analysis. Generally it appeared that the maxillary jaw and mandibular arch parameters contributed most to the discrimination to the four categories of subjects examined in this study.

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