The variability of some craniofacial dimensions

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Variations in craniofacial form are determined by two factors: genetics and environment. According to Scott[1] the parts of the skull which show the greatest amount of genetic variability are those which are most closely related developmentally to the chondrocranial and chondro-facial skeleton, namely the midline cranial base, the petrous temporal region developing in the cartilage of the otic capsule, the upper part of the nasal cavity, the orbital cavities and the lower border of the mandible. The regions in which environmental factors play a predominant role in form and size determination are the alveolar processes, the facial butress system and the parts to which muscles are attached. Those regions which take longer to reach adult proportions, such as the mandible, are more prone to environmental influences. Within the range of normality, the most variable areas of the cranio-facial skeleton are likely to exert a significant influence on jaw relationship and thus malocclusion type. Variability is, to some extent, a function of size, with larger variables exhibiting larger standard deviations than smaller variables. Nevertheless, with regard to the etiology of malocclusion in general and the relationship of the maxilla and mandible to one another in particular, the real variation of given dimensions will be of greater clinical importance than the percentage variation or coefficient of variation. At the same time, facial type within each malocclusion group may vary considerably but be of little relevance in determining jaw relationship. Cleall et al.,[2] by means of principal component analysis, showed vertical facial characteristics to be the most variable, although the significance of this in relation to the Angle classes was not studied. Arya et al.,[3] on the other hand, found mandibular dimensions to have a greater component of genetic variability than a number of other cranio-facial dimensions. From the standpoint of prediction of facial type, Kerr and Hirst[4] demonstrated, by means of stepwise discriminant analysis, the cranial base angle at 5 years

Abstract

The variability of eight linear and five angular dimensions measured on 124 lateral skull radiographs of 10-year-old boys was assessed by means of Bartlett's test for homogeneity of variances and Pitman's test for the comparison of correlated standard deviations. The linear dimensions which demonstrated the greatest variability within the four constituent Angle classes (N = 31) were mandibular body length, total cranial base length, total mandibular length and lower face height. The dimensions which demonstrated the least intra-group but greatest inter-group variability were maxillary length and Angle SNB. The Class II division 2 group exhibited the greatest variation in skeletal morphology; it is therefore postulated that its etiology is mainly dento-alveolar and soft tissue in origin.

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Key Words

Variability • Craniofacial dimensions • Occlusion

Table 1
Numbers and mean age of boys in each occlusal group.

Group	N	Age	S.D. (years)
I	31	10.37 ±	0.55
II¹	31	10.39 ±	0.67
II²	31	10.71 ±	0.86
III	31	10.15 ±	0.67

Table 2
Error of the Method $S_i = \sqrt{\frac{\Sigma d^2}{2(n-1)}}$

Variable	N	S_i (mm)	Variable	N	S_i (degrees)
S-N	20	0.60	Ba-S-N	20	0.10
Ba-N	20	0.35	S-Ar-Go	20	0.92
Ba-S	20	0.21	Ar-Go-Me	20	0.24
A-PMV	20	0.61	SNA	20	0.11
ANS-Me	20	0.51	SNB	20	0.29
Co-Go	20	0.45			
Go-Pog	20	0.10			
Co-Pog	20	0.10			

Table 3
Means and standard deviations of linear variables (mm) by group.

Variable	Group I Mean	I S.D.	II¹ Mean	II¹ S.D.	II² Mean	II² S.D.	III Mean	III S.D.
S-N	71.0	2.4	72.0	2.8	71.6	3.4	69.6	3.1
Ba-S	46.7	2.9	47.5	3.8	47.1	3.2	46.2	3.7
Ba-N	105.9	3.2	108.8	4.2	106.7	5.3	102.3	4.7
Co-Go	52.5	3.4	52.3	3.2	51.6	3.2	51.3	4.0
Go-Pog	72.3	3.3	68.5	3.4	69.4	5.0	71.1	3.4
Co-Pog	109.9	3.2	106.5	4.3	106.6	5.5	108.9	4.6
A-PMV	48.7	2.0	50.0	2.8	48.1	3.1	45.4	2.3
ANS-Me	65.5	4.5	65.7	3.9	62.8	5.5	62.2	4.7

to be a reliable discriminator between Class I and Class II relationships at 15 years in 73% of subjects. Nevertheless, maxillary length, facial height and mandibular length became more important with increasing age.

The present study is an attempt to investigate the variability of some cranio-facial dimensions commonly held to be of importance in determining jaw relationships.

Materials and methods

The material used in the present study was previously used in a study by Kerr and Adams.[5] It consisted of lateral skull radiographs of 124 male caucasians with a mean age of approximately 10 years (Table 1) drawn from the files of the Glasgow Dental Hospital and School, Scotland. None of the subjects had received orthodontic treatment; they were selected on the basis of incisor occlusion and divided into

Table 4
Means and standard deviations of angular variables (degrees) by group.

Variable	Group							
	I		II^1		II^2		III	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Ba-S-N	127.1	5.0	130.3	4.4	126.9	5.9	123.2	4.5
S-Ar-Go	140.0	6.4	137.6	5.1	139.5	6.6	141.3	5.4
Ar-Go-Me	131.2	5.7	131.3	4.8	129.9	5.9	132.3	5.0
SNA	80.8	2.9	80.5	3.9	79.9	3.6	79.9	3.4
SNB	78.1	2.6	73.9	3.6	75.9	3.1	81.9	3.6

Table 5
Bartlett's test for homogeneity of variances.

Variable	Test statistics
S-N	3.67
Ba-S	2.82
Ba-N	7.79
Co-Go	1.86
Go-Pog	8.09*
Co-Pog	8.14*
A-PMV	6.23
ANS-Me	3.65
Ba-S-N	3.63
S-Ar-Go	2.87
Ar-Go-Me	1.89
SNA	2.79
SNB	3.83

For test statistic 7.81 *$P < 0.05$.

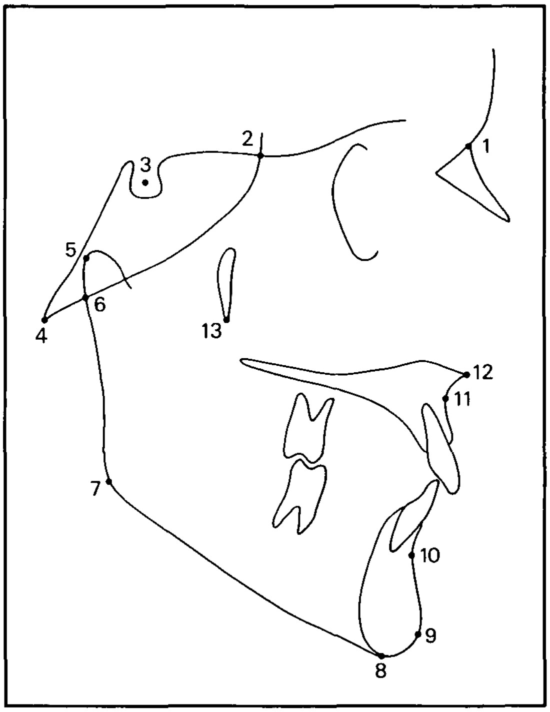

Figure 1
Points digitized on each radiograph — see text for details.

four Angle classes according to the following definitions:

Class I (I) = overjet and overbite 2-4 mm and incisal inclination within the normal range.

Class II division 1 (II/1) = overjet > 10 mm.

Class II division 2 (II/2) = central incisors to maxillary plane < 100° with a near normal overjet.

Class III (III) = both central incisors in lingual occlusion.

The strict criteria for selection thus minimized the possibility of disagreement about the occlusal classification.

Thirteen points were plotted on each radiograph on two occasions. The points were chosen to allow measurement of the shape and size of the principal areas of the cranio-facial skeleton thought to be contributory to the etiology of malocclusion of skeletal origin and their relationship to one another; namely the cranial base,

Table 6
Pitman's Test for comparison of correlated standard deviations for linear variables.
—— indicates no significant difference at 1% level.

I

Var :	A-PMV	S-N	Ba-S	Co-Pog	Ba-N	Go-Pog	Co-Go	ANS-Me
S.D. :	2.0	2.4	2.9	3.2	3.2	3.3	3.4	4.5

II^1

Var :	S-N	A-PMV	Co-Pog	Go-Pog	Ba-S	ANS-Me	Ba-N	Co-Pog
S.D. :	2.8	2.8	3.2	3.2	3.8	3.9	4.2	4.3

II^2

Var :	A-PMV	Ba-S	Co-Go	S-N	Go-Pog	Ba-N	Co-Pog	ANS-Me
S.D. :	3.1	3.2	3.2	3.4	5.0	5.3	5.5	5.5

III

Var :	A-PMV	S-N	Go-Pog	Ba-S	Co-Go	ANS-Me	Ba-N	Co-Pog
S.D. :	2.3	3.1	3.4	3.7	4.0	4.7	4.7	4.6

the maxilla and the mandible. The points are shown in Figure 1 as follows:
1 = Nasion; 2 = Ethmoid registration point; 3 = Sella; 4 = Basion; 5 = Condylion; 6 = Articulare; 7 = Gonion; 8 = Menton; 9 = Pogonion; 10 = Point B; 11 = Point A; 12 = Anterior Nasal Spine; 13 = Pterygomaxillary fissure inferior.

Pterygomaxillary Vertical (PMV) is formed by a line from points 2 to 13.

Eight linear and five angular variables were derived from the means of the two times of measurement:

Linear: anterior cranial base (S-N), posterior cranial base (Ba-S), total cranial base (Ba-N), mandibular ramus height (Co-Go), mandibular body length (Go-Pog), total mandibular length (Co-Pog), maxillary length (A-PMV) and lower face height (ANS-Me).

Angular: cranial base angle (Ba-S-N), joint angle (S-Ar-Go), gonial angle (Ar-Go-Me), maxillary prognathism (SNA) and mandibular prognathism (SNB).

Statistical methods

The double determinations of 20 randomly chosen radiographs were used to calculate the error of the method according to Dahlberg (Table 2). The means and standard deviations for each variable are given for each of the occlusal groups in Table 3 (linear variables) and Table 4 (angular variables).

In the first approach the standard deviations are compared between occlusal groups for each variable in turn. The null hypothesis of no difference between the standard deviations for the four groups was tested using Bartlett's Test (Snedecor and Cochran[6]). This test is based on the assumption that the data arise from normal distributions. Investigation of this assumption using histograms and normal probability plots raised no substantial concerns.

In the second approach the standard deviations were compared among variables within each occlusal group. This is a more difficult problem since the fact that different measurements on each individual are statistically dependent has to be taken into account. In addition, no simple global test exists. A test due to Pitman, however (Snedecor and Cochran[6]), permits the comparison of correlated standard deviations taken two at a time. The approach taken here is to carry out all possible pairwise comparisons of the standard deviations for the linear angular variables. To partially adjust for the multiple testing involved, significance was assessed at the 1% level. A useful method for displaying this rather complex analysis is illustrated in Tables 6 and 7. The variables are arranged in a row (usually) in increasing order of standard deviation. Groups of variables whose standard deviations cannot be judged, on the basis of Pitman's test, to be different, are connected by a straight line. These displays give an impression of the extent to which variables can be ordered or clustered in terms of the magnitude of their standard deviations.

Table 7
Pitman's Test for comparison of correlated standard deviations for angular variables.
—— indicates no significant difference at 1% level.

I

Var :	SNB	SNA	Ba-S-N	Ar-Go-Me	S-Ar-Go
S.D. :	2.6	2.9	5.0	5.7	6.4

II[1]

Var :	SNB	SNA	Ba-S-N	Ar-Go-Me	S-Ar-Go
S.D. :	3.6	3.9	4.4	4.8	5.1

II[2]

Var :	SNB	SNA	Ba-S-N	Ar-Go-Me	S-Ar-Go
S.D. :	3.1	3.6	5.9	5.9	6.6

III

Var :	SNA	SNB	Ba-S-N	Ar-Go-Me	S-Ar-Go
S.D. :	3.4	3.6	4.5	5.0	5.4

Results

Bartlett's Test (Table 5), shows that the standard deviations vary significantly ($P < 0.05$) between the occlusal groups for mandibular body length (Go-Pog) and total mandibular length (Co-Pog). Total cranial base (Ba-N) just fails to achieve statistical significance.

Pitman's test for the comparison of standard deviations for correlated variables showed the number of significant differences between standard deviations (when all pairwise comparisons within linear and angular measurements were considered) for each occlusal group to be as follows:

Class I	=	14
Class II division 1	=	5
Class II division 2	=	22
Class III	=	13

The pattern of significant differences is displayed in Tables 6 and 7. The level of variability in the data precludes the identification of clear clusters in the variables. However, some general patterns do emerge. For the linear variables, A-PMV, Ba-S and S-N tend to exhibit the lowest variability and Co-Pog, ANS-Me and Ba-N the highest variability. For the angular variables, SNA and SNB uniformly exhibit the lowest variability, while S-Ar-Go, Ar-Go-Me and Ba-S-N exhibit the highest.

Discussion

In this study of pre-pubescent boys, total mandibular length, mandibular body length and to a lesser extent, total cranial base, have shown the greatest difference in variation between occlusal groups. Reference to the standard deviations for these dimensions within each group shows a trend towards greater variability in the Class II division 2 and Class III groups and less variability in the Class I and Class II division 1 groups. Previous analysis of the same material[5] has shown the mean mandibular dimensions in the two Class II groups not to differ significantly from one another, while they differed significantly from the Class I and Class III groups. It is possible, therefore, that differences in cranial base length discriminate between the divisions of Class II and the two other groups by influencing mandibular position and therefore, prognathism.

From the number of significantly different correlated variances elicited by Pitman's Test, the Class II division 1 group appeared to be the most homogeneous while the Class II division 2 group appeared to be the most heterogeneous. Although Pitman's test did not generally elicit any distinct grouping of variables, the Class II division 2 group was the only one which demonstrated two clusters of variables exhibiting high and low variability for both the linear and angular dimensions. The linear variables concerned — mandibular body length, total cranial base, total mandibular length and lower face height — were more variable in this group than in any other and are therefore unlikely to have had any great influence on the occlusal relationship. This finding adds weight to the concept that Class II division 2 malocclusion is skeletally, the least well defined of the Angle classes; it is probable, therefore, that its etiology is less skeletal and more dento-alveolar and soft tissue in origin than the other three classes.

The dimensions showing the lowest variability within each group while also demonstrating a significant discrepancy in mean values between the groups, and which by inference characterized each group, were maxillary length and mandibular prognathism. While maxillary length may be important in determining a subject's occlusal class, the relative constancy of maxillary prognathism between groups confirmed that the size of the maxilla does not appear to influence its prognathism. Mandibular prognathism, as has previously been demonstrated,[5] is dependent upon both mandibular size and position and its emergence as a discriminator in the context demonstrates the complex nature of the interdependence of constituent craniofacial components.

The findings of this study support the contention of Arya et al.[3] regarding the high variability of mandibular dimensions in a similar age group to that studied here. Had an older age group been studied it might have been possible to comment on the findings of Cleall et al.[2] concerning vertical facial dimensions. It can be hypothesized, however, that as total mandibular length, mandibular body length and lower face height were among the more variable dimensions, and as they are acknowledged to increase in size until towards the end of the second decade, they may be more susceptible to environmental influences and thus orthodontic treatment.

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