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A MORPHOMETRIC STUDY OF THE CLASS III PATTERN RELATED TO HEADFORM

by

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Abstract

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Mandibular protrusive and mandibular retrusive regional anatomic relationships tend to characterize the brachycephalic and dolichocephalic headforms, respectively. The focus of the present study was to determine the assembly of regional relationships comprising the Caucasian dolichocephalic headform type which presents with a Class III malocclusion pattern. Sixty-one Caucasian and Afro-American individuals with Class III occlusions and 126 Caucasian and Afro-American individuals with Class I occlusions were included in the sample.The counterpart analysis of Enlow was selected for radiographic evalation, in order to assess the nature of anatomic assembly of regional morphologic components. The results indicate that the Class III dolichocephalic headform type is a variation of the dolichocephalic headform seen in the Class II/I A groups. The Class III headform group appeared to be heterogeneous. No statistically significant differences in the

magnitude of variable measurements were seen between the Class III Caucasian headform groups. Frequency percentage distributions were found to differ among the Class III groups. Marked differences within headform groups were seen between Class III/I B and Class II/I A groups, while the Class III and I B groups were similar. Subgroups appear to exist in the various headforms. Identification and description of these subgroups will allow one to understand more fully the biological basis for the resultant morphology. Once the control processes and timing of craniofacial growth are better understood, this information will be invaluable for understanding and planning treatments which influence craniofacial growth.

DEDICATED TO

My husband, Dan, whose love and support helped turn dreams and aspirations into reality

and

to my family, who have always encouraged me to reach for my goals

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INTRODUCTION

The craniofacial complex is made up of many regional counterpart relationships, each having a mandibular retrusive, neutral or mandibular protrusive effect. The composite of these regional effects will underlie a Class II or Class III malocclusion, or a Class I occlusion with either a Class II or a Class III tendency. It has been documented that the various regional mandibular protrusive relationships tend to characterize the brachycephalic type of headform and the mandibular retrusive relationships tend to characterize the dolichocephalic headform type (Bhat and Enlow 1985). The dinaric type of headform which has been described as a "brachycephalized-dolichocephalic" tends to be characterized by certain mandibular protrusive and mandibular retrusive features which frequently combine to produce a long nasomaxillary complex and a more prognathic mandible than is typical in the leptoproscopic pattern. Recent studies suggest that more than one anatomic type of dinaric form exists, but the anatomic features have not yet been described or classified (Bhat and Enlow 1985).

The purpose of this study has been to determine the nature of anatomic assembly of regional morphologic components that underlie the Class III malocclusion

pattern in the dolichocephalic headform. This variation of the dolichocephalic headform does not have the full complement of combinations of regional mandibular relationships that are identified with the typical dolichocephalic, leptoproscopic type of headform.

Certain regional counterpart relationships in the craniofacial complex were assessed using the counterpart analysis of Enlow and others (1971A). This information was used to interpret the biological basis for the resultant individual morphology.

LITERATURE REVIEW

Class III malocclusion and mandibular prognathism

Class III malocclusion is not considered to be a single clinical entity (Ellis 1984; Sanborn 1955). Many different combinations of skeletal and dental parts may result in Class III malocclusion. Craniofacial components mentioned in the etiology of Class III include the maxilla, the mandible, the cranial base, the temporo-mandibular articulation and the alveolar bases.

Studies undertaken to try to identify the components of Class III malocclusion vary in results according to the types of measurements used - linear, angular, etc. Basically, the components are characterized by pure maxillary retrusion, pure mandibular protrusion, maxillary retrusion combined with mandibular protrusion and orthognathic maxilla and mandible. The most common method used to determine maxillary retrognathism and mandibular prognathism are the angles Sella-Nasion-A point(SNA) and Sella-Nasion-B point(SNB). Williams and Andersen (1986) point out the shortcomings of interpreting SNA angle and maxillary development as such. The position of Nasion and the length of the anterior cranial base can greatly influence the SNA angle. In studying their Class III cases, Williams and Andersen (1986) found the mandible to be prognathic in 40% of the

sample when measured linearly and in 75% of the sample when measured as an angle.

Angle, in his classic study "Classification of Malocclusion" (1899), described the Class III malocclusion as a condition in which "the relationship of the jaws is abnormal, all the lower teeth occluding mesial to normal the width of one bicuspid or even more in extreme cases." He proposes several causes for discrepancy in the size of the jaws: the maxillary bones may not develop fully; the angle of the lower jaws may become more obtuse than normal; the lower jaw may over-develop; or the temporo-maxillary articulation may be located more anteriorly than normal. One subdivision of Class III is also described in which there exists a unilateral mesiocclusion.

Alling (1961) elaborates on the consequences of mandibular prognathism. He states that mandibular prognathic deformities of the oral cavity may cause prosthetic, periodontic, orthodontic, esthetic, masticatory and digestive, general dental, speech and psychological complications. Patients commonly complain of their inability to eat properly in a social sense and to masticate efficiently for adequate nutritive intake.

A Class III "dental" malocclusion may develop independently or together with a Class III "skeletal" pattern. Likewise, a true or relative mandibular

protrusion may involve either a Class I or Class III occlusion. Class III dental occlusion is usually present, to a greater or lesser degree, in mandibular prognathism (Litton et al. 1970). Horowitz (1969) felt that the Class III dental occlusion present in mandibular prognathism constitutes only one part of the syndrome.

Prediction of the Class III pattern

To be able to predict the occurrence or course of Class III growth would provide an advantage for clinician. It seems, however, that growth in the Class III patient is all but predictable. Bjork and Palling (1954) state that because the age changes in facial prognathism vary considerably among individuals, and also as the differential displacement of the jaws may occur in either direction, individual deviations from the general growth pattern may be considerable. They go on to say that it is not possible to predict jaw relations at a pre-pubescent stage. Stockli (1970) concurs with Bjork and Palling. He found that the Class III type case does not proceed along a stable, i.e. predictable, growth pattern. Observations during an early phase of development have not been shown to be indicative of the development at a later phase. Cephalometric analysis has not revealed factors in advance which lead to the variations in ultimate Class III development. Due to the number of

etiologic and developmental patterns resulting in a large variation of morphologic traits, there is no known key to prediction of Class III pattern (Williams and Andersen 1986). A genetic basis for prediction (cephalometric) based upon the facial type in a growing child appears almost completely lacking. However, reliability of prediction can be somewhat enhanced if parents' craniofacial morphology is taken into consideration (Nakasima, Nakata and Takahama 1982).

Stability of the Class III pattern

Emrich, Brodie and Blayney (1965) demonstrated the high stability of Class III malocclusion. In their study, 7654 children were examined at both 6-8 years and 12-14 years. Ninety-three percent were classified as Class III at the first examination and remained Class III at the second examination. Changes into or out of the Class III category were as follows: 0.36% normal to Class III, 0.32% Class I to Class III, 0% Class II to Class III, 3% Class III to normal, 2% Class III to Class I, 2% Class III to Class II.

Incidence

The incidence of Class III malocclusion reported in the literature is varied. The incidence in the United States has been reported to be as low as 1% (Ast, Carlos

and Cons 1965) and as high as 12.2% (Huber and Reynolds 1946). Other workers have found the incidence to be between 2-9% (Altemus 1959: Negro 4.99%; Angle 1899: 3.4%; Bowbeer and Day 1969: Negro 7%, Caucasian 3%; Emrich, Brodie and Blayney 1965: Negro 3%; Garner 1985: Negro 8.7%; Horowitz and Doyle 1970: Negro 1.5%, Caucasian 1.9%; Krogman 1951: male 2.2%, female 1.2%; Massler and Frankel 1951: Caucasian 9.4%).

Heredity

Evidence has shown that heredity plays a role in malocclusion and facial dimensions. The familial tendency of Class III has been demonstrated in the Habsberg family line (Bertram 1959). Stiles and Luke (1953) suggested that mandibular prognathism is probably inherited by means of a dominant gene with an unknown degree of reduced penetrance. A polygenic model of inheritance with a threshold for expression for Class III malocclusion has also been proposed (Litton et al. 1970). Nakasima, Nakata and Takahama (1982) found the familial correlations in Class II and Class III malocclusions compatible with a correlation coefficient of 0.50 expected under the polygenic model of inheritance.

Studies have been done on the hereditability of specific craniofacial components. Nakasima, Nakata and Takahama (1982) found correlations between parent and

offspring to be stronger for the skeletal measurements of Class II and Class III. Thus, they concluded that the skeletal pattern was more directly related to genetic factors. Hunter, Balbach and Lamphiear (1970) saw the relationships between father and offspring were statistically the stongest, especially for mandibular dimensions.

Hughes and Moore (1941, 1942) studied the role of heredity in facial growth. Alveolar bone characteristics and the shape of the mandibular angle were found to be primarily dependent upon hereditary factors. Heredity provided 85% of the variation shown in the dentition and its growth. The size and configuration of the maxilla and mandible are 70-80% due to heredity. The authors concluded that hereditary factors are involved in the production of malocclusion although the pattern according to occlusal type is not clear. Hughes and Moore felt the only parts of the dentofacial complex which were easy to modify with treatment were the alveolar portions of the jaws. Changes in the maxilla and mandible can be produced by functional adjustments over long periods of time.

There is strong evidence for a partial dominance of the deficiency over the excess in craniofacial components (Moore and Hughes 1942). Hereditary Class III is usually due to a maxillary deficiency or an obtuse mandibular

angle rather than a mandibular excess. A significant factor found was a tendency toward deficiency in the absolute size of the maxilla. Children tend to follow the parental pattern in inheriting maxillary deficiency or excess. As for the absolute size of the mandible, there was little tendency for mandibular excess to be transmitted. Excessive absolute size of the mandible is rare in children (1.6%) and infrequent in parents (9.5%). When one or both parents presented with a mandibular deficiency, there was a marked tendency for a deficient mandible in the children. There was a pronounced tendency for parents to transmit deficiency of ramus size to children beyond the hereditary expectation. In children, deficiences in ramus size occurred in 50.8% of the sample studied, where excess size occurred in only 1.6% of the sample . The absolute size of the body of the ramus conforms to parental patterns. There was a tendency for parents with a medium absolute size of the body of the mandible to produce a deficiency more frequently than excess.

The question of the role of genetics versus the environment has been around for a long time. Moore and Hughes (1942) commented that "genetic factors can never exist independent of environment and environmental influences cannot affect or even seriously modify a structure of genetic origin." They felt that hereditary

variations are far more common than environmental variations. Class III malocclusions are supposedly more difficult to create environmentally than some Class I malocclusions.

Etiologies

General

Litton and others (1970) suggested the occurrence of certain etiologic environmental factors in Class II malocclusion: enlarged tonsils, mouth breathing, congenital anomalies, diseases of pituitary gland, hormonal disturbances, habits and posture. Rakosi and Schilli (1981) consider a flat, anteriorly located tongue to be a local genetic factor in the anterior positioning of the mandible and a cause of Class III malocclusion.

Pascoe, Hayward and Costich (1960) report that the etiology of prognathic facial disharmony is difficult to determine since it is a result of the aberration of one or more factors: heredity, endocrines, growth of the cranial base, appositional bone growth, bone resorption, alveolar process development and functional activity. Thompson and Jurgens (1956) and Rowe (1960) list other factors which may cause mandibular prognathism. These include congenital malformations (cleft palate, macroglossia due to hemangioma or lymphangioma, achondroplasia, cleidocranial dysostosis, oxycephaly,

leontiasis, osteopetrosis), endocrinopathy (acromegaly, hypogonadism, cretinism), posttraumatic forms (fractures, burns), and postinfectious forms (mandibular infection, and especially, osteomyelitis, tonsilitis, adenoiditis).

Hopkin (1965) reported that anteroposterior jaw relationships and occlusion may be affected by three factors: maxillary growth, mandibular growth, growth changes in the base of the skull which result in changes in the position of the articular fossa relative to the maxilla. He feels that, normally, mandibular growth is greater than maxillary growth, but the mandibular growth is offset by the relative backward movement of articulare.

Joffe (1965) described the etiology of maxillary deficiency as an upset in the normal growth mechanism responsible for the downward and forward progression of the nasomaxilary complex. He also reports mandibular overgrowths being due to either an excessive amount of growth of the mandible or an alteration in mandibular shape. Joffe stated that most overgrowths probably have a genetic background.

In his Class III cephalometric study, Stapf (1948) supported the idea that Class III is a consequence of continued growth beyond the normal. This is evidenced by the regularity of points gonion and gnathion, the parallelism of the lower borders of the mandibles, the

almost parallel nasal floors and the constant nasal height between the Class III and normal pattern.

Rakosi (1970), comparing Class II patients with Class III patients, found the problem is not localized in one jaw but in the linear and angular correlations of the whole facial skeleton. Class II had a posteriorly rotated mandible and Class III had an anteriorly rotated mandible. Significant differences from normal in the Class III were in the angle of convexity, S-Ar-Go, gonial angle and mandibular rotation angle. Comparing Class III with normal, Class III had a mandible which was too long and a retropositoned maxilla along with several other parts of the facial skeleton.

Cranial Base

The cranial base has been implicated by many people as a causative factor in producing Class III relationships. Hopkin, Houston and James (1968) found a progressive and significant increase for all the cranial base dimensions from the Class III group through the Class I group to the Class II group. They state that the dimensions of the cranial base are a major factor in determining anteroposterior relationships of the jaws and dental arches which must be taken into account in diagnosis and treatment planning. Guyer and others (1986) have found the cranial base (S-Ba) to be significantly

longer in the Class III population.

The relationship between the length of the anterior cranial base and maxillary protrusion has been studied by many authors. The anterior cranial base (N-S) is shorter in Class III types (Sanborn 1955; Jacobson et al. 1974). Williams and Andersen (1986) found a correlation between length of the anterior cranial base and maxillary development. Wei (1969) reported a minor association between the lengths of the cranial base and maxillary prognathism in his sample of Class III subjects. He felt the part played by the length of the jaw bases may assume a more important role in individual variations in prognathism than suggested by Bjork (1951). Also noted by Wei - the influence of the cranial base deflection on prognathism was probably closely related to the degree of maxillary protrusion produced.

An increased cranial base deflection has been noted by Bjork (1951), Horowitz, Converse and Gerstman (1969), and Kerr and Tenhave (1988). Sanborn found no differences in saddle angles (N-S-Art) for Class III and normal occlusions.

Position of the Condyles Relative to the Cranial Base

Increased vertical development between sella and the articular fossa had been suggested as an etiologic factor in Class III by Droel and Isaacson (1972). Williams and

Andersen's 1986 studies supported this concept.

Maxilla

Jacobson and others (1974) felt that Class III's had a relatively distally positioned maxilla. Horowitz, Converse and Gerstman (1969) found the position of the maxilla was not substantially different in mandibular prognathic and normal groups, although the similar A-P dimension of the maxilla found in open bite and non-open bite mandibular prognathism appeared to be a significant factor in the etiology of the deformity.

The Class III maxilla is often retrusive as demonstrated by the SNA angle (Guyer et al. 1986; Sanborn 1955; Joffe 1965), and Point A to Nasion perpendicular (Guyer et al. 1986). The mean difference between the effective maxillary length (Condylion to Point A) and the effective mandibular length (Condylion to Gnathion) in the Class III is at least 6mm greater than the Class I mean at all ages (Guyer et al. 1986). The effective length of the maxilla in Class III is significantly shorter. Williams and Andersen (1986) showed 50% of their Class III sample to possess a short retrognathic maxilla when measured linearly. The length of the maxilla in relation to the cranial base was reduced in 25% of the cases.

Jones (1973) compared maxillary basal lengths in

skeletal Class III cases and a control group. The anteroposterior position of the maxillary base was significantly related to the length of the maxillary base. The smaller maxillary base is more retrognathic. A strong correlation exists between maxillary-mandibular plane angles and maxillary length. High mandibular plane angles are associated with short maxillary bases. With increased downward displacement of the Gnathion, the maxillary length tends to decrease.

Mandible

The position of the mandible is believed by some to play a greater role in mandibular prognathism than the size of either jaw (Kerr and Tenhave 1988; Horowitz, Converse and Gerstman 1969). Kerr and Tenhave (1988) have shown that the mandibular dimensions in Class III and controls are similar and concluded that the forward positioning of the condyle and mandibular symphysis in the horizontal plane is the product of cranial base morphology and any anterior displacement. Jacobson and others (1974) also found the position of the head of the condyle in Class III to be located farther anterior than normal. Another possible etiology of mandibular prognathism is the forward position of the condyles and articular fossa with reference to the cranial base (Maj, Luzi and Lucchese 1958; Dietrich 1970; Kerr and Tenhave

1988; Jacobson et al. 1974). Droel and Isaacson (1972) have found the glenoid fossa position to correlate with the skeletal discrepancy. The fossa was located more superiorly in high mandibular plane angles and more inferiorly in low mandibular plane angles. The horizontal sella-fossa distance had a significant correlation with the ANB angle. Although a cause and effect relationship could not be determined, Class III skeletal discrepancies had the fossa positioned more anteriorly than Class I skeletal relationships. The fossa was positioned more posteriorly in the Class II skeletal discrepancies. Forward positioning of the fossa can be a reflected in the angles formed by the ramus and cranial base. Sanborn (1955) showed significantly smaller angles for the Class III sample for S-Art-Go, N-S-Go, Art-Go with SN, FH, palatal and occlusal planes.

Maj, Luzi and Lucchese (1958) indicate that 78% of their Class III cases with great differences in bony base ratios (CoM-CoANS) are due primarily to an increased length of the lower jaw and, less importantly, a forward position of the condyles with reference to the cranial base. The increased length of the mandible is due mainly to over-development of the body associated with a decreased ramal height. The gonial angle is not disturbed.

Over-development of the mandible is believed by many

to be one contributing cause of Class III relationships. Guyer and others (1986) found the Class III mandibles to have a 3-6mm greater length from Condylion to Gnathion than the Class I mandibles. Joffe (1965) also found a greater condylion-gnathion distance in prognathic mandibles. However, Smith and Chambers (1962) state that "no one has proved that prognathic mandibles develop by any mechanism or in a manner greatly different from that of normal mandibles." Thus they feel the prognathic mandible seems to be an expression of quantitative rather than qualitative growth. Stapf (1948) also supported the idea of mandibular overgrowth.

Lande (1952) found the mean tendency for increased prognathism to occur after 7 years of age. The mandible tended to become more prognathic with very little anteroposterior change in the maxilla. This is in contrast to McCallin's study (1956) in which he did not observe any cases where the mandible grows forward more rapidly than the maxilla so that mandibular prognathism alone increases.

Similarities exist between Class III and Class I mandibles (Kerr and Tenhave 1988). Mandibular body length has been shown to be similar (Sanborn 1955; Horowitz , Converse and Gerstman 1969). Length of the ramus (Articulare to Gonion) was shown to be similar (Sanborn 1955; Williams and Andersen 1986).

Typologies

The Class III malocclusion has been categorized by many authors. Categories mentioned include: incomplete growth of the maxilla (horizontal and/or vertical dimension), abnormally shaped mandible, overgrowth of the mandible, anterior temporomandibular articulation, short anterior cranial base resulting in a horizontally short maxillary complex, position of the mandible, increased cranial base flexion, and abnormal inclination of the ramus. Angle's ideas for the etiology of Class III malocclusion still hold true today.

Sanborn (1955) felt the role of the mandible in Class III malocclusion is not mainly one of overgrowth, but one of malformation or abnormal morphologic arrangement of the ramus and body in conjunction with a poor relation to the neurocranium and upper face. In a sample of Class III patients, he found 45% to possess a normal maxilla with a prognathic mandible, 33% with a short maxilla and normal mandible, 9.5% with a normal maxilla and mandible, and 9.5% to have a short maxilla and prognathic mandible.

Dietrich (1970) identified six types of skeletal relationships comprising the Class III. A retrognathic maxilla was implicated in 37.5% of the cases studied. The maxillary retrognathism was caused mainly by quantitative deviations, the horizontal length of the maxilla being

deficient. Positional deviations were minor. An orthognathic mandible and maxilla were found in 28.5% of the Class III cases. Mandibular prognathism, resulting mainly from a positional deviation of the mandible in relation to the cranial base, was found in 25% of the cases. Here, quantitative deviations did not reach a significant level. The last three types of Class III - maxillary and mandibular prognathism, maxillary and mandibular retrognathism and maxillary retrognathism combined with mandibular prognathism - accounted for 9% of the cases.

Bjork (1951) states that increased mandibular prognathism depends upon an increased length of the mandible in relation to the length of the cranial base as a whole, an increased deflection of the cranial base or a more forward inclination of the ramus.

Stiles and Luke (1953) found mandibular prognathism to be caused by an underdeveloped maxilla or an increased obtuseness in the mandibular angle.

Bimler (1970) classified Class III into three types. The first type, micro-rhinic dysplasia (mandibular hyperflexion), results from a reduced midfacial height (maxillary complex). The second type, leptoidysplasia (pan-dysplastic), has a reduction in all sagittal dimensions except for the length of the mandible which was increased. The last type, microtic-dysplasia

(temporal position), results in a forward position of the temporomandibular joints.

Williams and Andersen (1986) found the length of the mandible to be excessive using linear measurements along the occlusal plane in 17% of their Class III cases. A retrognathic maxilla and normal mandible were seen in 37% of the cases, while 29% had a normal maxilla and prognathic mandible.

Pascoe, Hayward and Costich (1960) classify mandibular prognathism into five types. Type A has a maxilla within the normal range of prognathism and a mandible within the normal range of prognathism. Here, the Class III is not due to an overgrowth of parts, but is secondary to the relationship of the horizontal and vertical cranial base components. They consider this type true prognathism of genetic origin. Type B involves a normal maxilla and a prognathic mandible. The mandible develops beyond normal. The effect of growth of the cranial base on jaw position must be considered as a factor in producing or initiating this deformity. Type C has a horizontally short maxilla and a normal or above normal mandible. Deficient maxillary growth may account for 33% of all mandibular prognathism. Type D corresponds to a normal maxilla and mandible. This is a basilar prognathism due to the relationship of the cranial base and mandibular growth at the chin. The last

type, E, combines a normal maxilla, a prognathic mandible, increased lower third of the face, anterior openbite and a downward warping of the mandible.

Jacobson and others (1974) found the most significant difference from normal in Class III to be the ANB angle, with the mandible being more prognathic. SNB was significantly greater in adults than children. SNA was the same in the two groups. These authors found Class III malocclusion in adults to fall into six groups: normal maxilla with a prognathic mandible (male - 40%, female - 55%), retrognathic maxilla with a normal mandible (male - 28%, female - 23%), normal maxilla with a normal mandible (male - 22%, female - 6%), prognathic maxilla and mandible (male - 6%, female - 6%), retrognathic maxilla with a prognathic mandible (male - 3%, female - 6%), retrognathic maxilla and mandible (male - 0%, female - 3%). Sixty percent of the children with Class III occlusion had a normal maxilla and mandible. The other forty percent were evenly distributed according to the six categories.

Ellis and McNamara's study of adult Class III malocclusion showed that 65-67% of the entire sample had a retrusive maxilla (30.1% with a mandibular skeletal protrusion, 19.5% with a normal mandibular skeleton). Pure maxillary retrusion and pure mandibular protrusion were seen in 19.5% and 19.2% of the cases respectively.

Maxillary and mandibular protrusion was found in 15% of the cases.

Gonial angle

Stapf (1948) demonstrated differences between normal and Class III cases occurring in the mandible. The angle formed by the symphysis and the lower border of the mandible differs in the two groups. Also, the angle at which the occlusal plane is placed in the pattern differs.

Straight-line morphology of the mandible is another factor relating to a greater total mandibular length (Joffe 1965; Jacobson et al. 1974). This type of morphology results from an obtuse gonial angle and steeper mandibular plane (Jacobson et al. 1974). A more obtuse gonial angle has been seen by many authors (Joffe 1965; Jacobson et al. 1974; Sanborn 1955; Guyer et al. 1986; Williams and Andersen 1986). Bjork showed that mesial occlusion may be associated with a large or small gonial angle, although on the average it was a few degrees higher (cited by Jensen and Palling 1954).

Jensen and Palling did a survey on the gonial angle in humans in 1954. The gonial angle in humans was found to be obtuse and varied from 100-148 degrees. Hrdlicka (1940) found the gonial angle greatest in Caucasions, nearly so in Negroes, low in Melanesians and markedly

lower in American Indians (cited by Jensen and Palling 1954). Usually the angle is 3-5 degrees larger in females. Studies have shown conflicting findings relating gonial angle to headform. The size of the angle appears dependent upon the proportion of the height of the ramus to the length of the body of the mandible (Hellman 1929). Also, the gonial angle is subject to several conditioning terms such as race, age and sex.

Mandibular plane angle

High and low mandibular plane angles have both been named one of the main features in Class III malocclusion. Steep mandibular plane angles have been shown by Sanborn (1955); Joffe (1965); Jacobson and others (1974); Guyer and others (1986); and Ellis and McNamrara (1984). Lande (1952) found that prognathism was associated with a decrease in the inclination of the lower border of the mandible.

McCallin (1956) was one of the first investigators to distinguish Class III in terms of two extreme morphological types, although he admits that a statistical analysis of cases would probably show a smooth distribution of variations between the two types. The first type described has the features of a long mandible with a gonial angle above average, an anteroposteriorly short maxilla which is contracted

laterally, and usually, a large intermaxillary space anteriorly. The second type of Class III has a long mandibular body with an average or below average gonial angle, and an average length for the maxilla without lateral contraction. The intermaxillary space is average. A study by Williams and Andersen (1986) did not support the concept of two morphologically separate groups (high and low angle types). Mills (1966) felt the division of Class III into two groups based upon the maxillomandibular angle would seem to be false when the distribution of this angle is so close to a normal one with the modal value close to the mean.

Siriwat and Jarabak (1985) looked at possible associations between Angle types of malocclusions and facial morphology (hyper-, normo- and hypo-divergent patterns). They found the Class III to dominate in the hyperdivergent subjects, but the highest incidence of Class III occurred in the hypodivergent group (18% hyperdivergent, 31.2% normo-divergent, 50% hypodivergent). Ellis and McNamara (1984) found 69% of adults with Class III malocclusion had mandibular plane angles greater than 27.2 degrees. Twenty percent had a mandibular plane angle less than 21 degrees. Jacobson and others (1974) found a general tendency in the Class III sample toward an open bite or divergent skeletal pattern.

Openbite

Horowitz, Converse and Gerstman (1969) looked at mandibular prognathism with overbite and open bite. The prognathic group with overbite had a more anterior position of the ramus and body of the mandible relative to the cranial base (Class III due to position). The prognathic group with an open bite had a short ramus height with an obtuse gonial angle (Class III due to mandibular morphology). In their study, a multivariate analysis provided clear evidence of two distinct craniofacial patterns in prognathism. Ellis and McNamara (1984) also studied the components of adult Class III open bite malocclusion. One third of their Class III sample had an open bite, and high mandibular plane angles were seen in the open bite group. Also seen in this group were larger gonial angles, downward and backward position of the ramus and a short posterior facial height. Overeruption of the molars can contribute to the open bite.

Facial height

The Class III occlusion can include either an excessive or a decreased facial height. Kerr and Tenhave (1988) found shorter lower facial heights in their samples. Excessive lower anterior facial height was seen by Ellis and McNamara (1984); Guyer and others (1986),

Jacobson and others (1974), and Ridell, Soremark and Lundberg (1971). Stapf (1948) noted that one of the characteristics of Class III is an elongated face. Bjork (1954) found the development in the length of the face is not related to occlusion type.

Dentoalveolar components

Bjork (1954) stated that development of facial components appears to be independent of the development of the dento-alveolar components. The dento-alveolar components, however, are intimately dependent on the development of at least one facial component, which is the sagittal jaw relation. Compensatory dento-alveolar changes predominate during adolescence. Bjork (1951) also found that growth changes occurring in the incisal inclination and occlusion are intimately connected with growth changes in facial shape as a whole. Lande (1952) noted that alveolar bone growth does not keep pace with skeletal bone growth. BJork (1954) found alveolar prognathism to vary more in the lower jaw in all respects.

Some aspects of dental components have been related to Class III. Reduced lower molar height (Kerr and Tenhave 1988), maxillary incisor proclination/protrusion (Sanborn 1955; Jacobson et al. 1974), mandibular incisor retrusion (Sanborn 1955), greater incisal angle (Joffe

1965) and posteriorly positioned tooth row relative to the body of the mandible (Horowitz, Converse and Gerstman 1969) have all been documented. Varying results were obtained by Kerr and Tenhave (1988) in that they found no evidence of upper incisor inclination in their Class III sample.

Mandibular closure paths

Some authors have commented on overclosure or anterior displacement in some Class III cases. There were people who believed that during closure, some patients' mandibles were being displaced anteriorly due to incisor interferences. There was concern that cephalograms taken in the centric occlusion position would not reflect the true skeletal position. It was felt that after the incisor interferences were relieved the mandible would drop backward and the condyles would return to centric fossa position.

Slattery (1988) compared Class III malocclusion with and without displacement. He found significant differences in the two groups. The anterior displacement group showed a more forward rotation from the cranial base producing increased prognathism (maxillary and mandibular) and reduced anterior facial height. Cranial base dimensions were reduced in the displacement group, but not significantly so, and such reductions were

probably a contributing influence in this situation. No differences in the gonial angle were found between groups.

Gravley (1984) also studied mandibular closure paths in Class III relationships. He found little or no residual mandibular displacement in most Class III incisor relationships when the posterior teeth are in contact. Forward displacement to disengage incisors is counteracted by a backward movement of the condyles as further closure takes place. The finding that the condyle returns to the centric position when the posterior teeth are in occlusion is in agreement with Mills (1966), Hopper (1955), and Ballard (1955). Mills (1966) states that the 'pseudo' Class III caused by envirnomental factors must be exceedingly rare. Gravely (1984) found residual displacement may persist in only a few patients, especially in those with small overbites. Gravely (1984) also compared conventional cephalograms to those in edge to edge position. Apparent differences in skeletal pattern assessments were related to changes in vertical height rather than displacement. In most cases, the skeletal pattern was reasonably reflected in the conventional cephalogram. Mills (1966) saw some increase in lower facial height following treatment but which later disappears. He found no evidence that overclosure

is either present or eliminated during treatment.

Form and Function

Ahlgren (1970) studied the form and function of Angle Class III malocclusion by means of cephalometrics and electromyography. The Class III group showed a mean gonial angle of 131.7 degrees, while the normal groups mean gonial angle was 123.9 degrees. A significant correlation was found between the ANB angle and EMG potential in the Class III. An inverse relationship was found between the peak integrated EMG and the size of the gonial angle. Inhibited muscle activity during incising and chewing can create a large gonial angle. Ahlgren hypothesizes that it may be that hypofunction of Class III cases over a long period of time can affect the growth of the maxilla and mandible.

Prognosis

The prognosis for Class III malocclusion has been studied by Dietrich (1970). Skeletal Class III with an orthognathic mandible and maxilla had a more favorable prognosis than mandibular prognathism and maxillary retrognathism. Between mandibular prognathism and maxillary retrognathism, no obvious prognostic difference was found.

Morphology and response to treatment

The morphology of the individual influences the response to treatment. Mills (1966) did not find evidence that treatment of Class III had any permanent effect on the skeletal pattern besides some remodeling around point A. Enlow and others (1988) described two basic categories of Class II individuals: Type A with a protrusive maxillary point related to B point, as projected to the functional occlusal plane, and Type B with a protrusive mandibular B point relative to A point. Each type was seen to have different morphogenic potentials in response to Class II treatment using the Frankel appliance. One craniofacial type (A) exhibited dominant retrusive effects while the other type (B) exhibited dominant protrusive effects. DiPalma (1982) found that vertical pull chin cups and functional regulators affected the mandible and its counterparts differently in patients with Class II and Class III skeletal tendencies (DiPalma 1982).

Stensland, Wisth and Boe (1988) retrospectively looked at dentofacial changes in children with negative overjet treated by a combined orthodontic and orthopedic approach. Results were grouped according to good and poor results obtained. The pretreatment radiographs of the poor result group showed a shorter cranial base

(N-S), the jaw angle more anterior, the angle of the jaw more open and the chin prominance more acute. They found that major differences in "good" and "poor" treatment groups develop later in growth. The size of the jaw angle seemed to be an important parameter for the treatment response. It was significantly less in the good result
group pretreatment and was significantly reduced during treatment.

Rakosi and Schilli (1981) reported on the treatment possibilities in the Class III patient. For a patient in the deciduous dentition with a long mandible, growth inhibition is possible for skeletal improvement. In the mixed dentition, control of mandibular growth is possible by controlling incisal guidance. If the problem is a short maxilla in the deciduous dentition, improvement of the midface convexity is especially good during the eruption of the maxillary incisors. Class III correction in the permanent dentition is possible by partial skeletal improvement and dentoalveolar compensation.

Gender differences

Observations of gender differences and similarities in general facial morphology have been studied and most report little or no significant differences (Ellis and

McNamara 1984; Massler and Frankel 1951; Emrich, Brodie and Blayney 1965). Gender differences that do exist were most often reported for linear measurements; angular measurements are similar between the sexes (Ridell, Soremark and Lundberg 1971). The later investigators reported significant differences mainly in linear mandibular measurements in normal and mandibular protrusive subjects. The differences observed between male and female in the normal group were the same as those between the sexes in the mandibular protrusion group. In comparing normal and mandibular protrusive males and normal and mandibular protrusive females, differences were observed for linear and angular measurements. Stapf (1948) found typing of Class III facial patterns appears to be independent of sex or age in most circumstances. Siriwat and Jarabak (1985) reported a greater tendency toward prognathism in males. Class III females showed a significantly greater mean total effective mandibular length and a more divergent skeletal profile in adults and children (Jacobson et al. 1974). Emrich, Brodie and Blayney (1965) showed a lack of intersex differences in their study except in Negroes at the 12-14 year old level. Here, twice as many males as females had Class III occlusion.

Ethnic considerations

Studies have shown that Class III facial types differ among ethnic populations. Important features in influencing prognathism in Chinese males were size of maxillary jaw base and degree of maxillary protrusion (Wei 1969). Enlow and others (1982) found differences in Class III morphology in Caucasian, Oriental and Afro-American individuals. Caucasians and Orientals tend to have a more upright inclination of the middle cranial fossa with a forward and upward ramus orientation, while Afro-Americans have a more anteriorly inclined middle cranial fossa and severe backward and downward rotation of the ramus. In about half of the cases, a narrow ramus showed compensation for a Class III relationship in Caucasians. Afro-Americans characteristically have a broad ramus in Class I as well as Class III. The vertical height of the maxillae in the Afro-American Class III group were somewhat shorter than in the Caucasian groups and Afro-American Class I and Class II groups. The Afro-American Class III mandibular arch was not as long as in Caucasians. Class III in Caucasians were found to have a greater incidence of vertically short nasomaxillary complexes. Emrich, Brodie and Blayney (1965) showed that Afro-Americans have Class III malocclusions three times more often than Caucasians at

the same age. The characteristically broad ramus of Afro-Americans probably accounts for the greater incidence of Class III.

Craniofacial growth

Normal growth patterns have been described by Brodie (1941) and Bjork (1954). Brodie presented documentation that a given basic morphogenetic pattern once attained (at about 3 months or earlier) does not change up to 8 years of age. Bjork studied adolescent age changes and found that mandibular prognathy on an average increases somewhat in relation to the upper jaw, causing the profile to straighten and the lower jaw to become more protrusive. Enlow and others (1969) stated that growth can sustain, improve or aggravate the original balance or imbalance.

Enlow and Harris (1964) studied the postnatal morphogenic growth of the mandible. Normal mandibular growth occurs by area relocation along the V principle (described later). The condylar neck is progressively relocated into the enlarging ramus with the condyle growing in a cephalic and posterior direction. The anterior border of the ramus is progressively relocated in a posterior direction enlarging the body. The width of the ramus is achieved by additions at the posterior

and buccal surfaces of the ramus. The body of the mandible is lengthened by remodeling from the posteriorly relocating ramus. Deposition of bone occurs along its basal margin. The chin is created by a variable yet characteristic periosteal recession in the lingual region along with long-term deposition on the protuberence.

Normal growth of the maxilla occurs by growth at the tuberosity with resorption on its anterior surface. The palate is relocated in an inferior direction (Enlow 1982).

Intrinsic craniofacial compensation

The growth of the human skull has many naturally occurring intrinsic craniofacial compensations. Compensatory dento-alveolar changes predominate during adolescence, and these compensatory and dysplastic variations tend, more or less, to cancel each other out with age (Bjork and Palling 1954). "A single morphologic feature does not ordinarily produce such protrusive relationships because the presence of a structural imbalance in any one area also affects the nature of balance in other areas as well. (Enlow, Kuroda and Lewis 1971b)." Thus all factors act in a cumulative, composite manner. Class II and Class III cases show a degree of intrinsic compensation, but it is in the Class IIA and

the Class III cases that most compensatory mechanisms fall short (Enlow, Kuroda and Lewis 1971b).

Headform

Human headform is classified according to the cranial index (skeletal measurement) or cephalic index (soft tissue measurement). These indices are determined by head breadth and head width ratios. Hrdlicka (1952) gives reference to the cranial index with classifications for ultradolichocrany, hyperdolichocrany, dolichocrany, mesocrany, brachycrany, hyperbrachycrany and ultrabrachycrany. Hrdlicka also references the cephalic index with classifications for hyperdolicocephaly, dolicocephaly, mesocephaly, brachycephaly and hyperbrachycephaly. Enlow (1982) describes another, separate type of headform, the dinaric, which has both dolicocephalic and brachycephalic features.

Headform and facial pattern

The dolicocephalic headform and associated facial pattern have many typical features (Enlow 1982). The flexure between the middle cranial fossa and the anterior cranial fossa is relatively open. The cranial base is more elongate anterior-posteriorly and narrow laterally. The horizontally long cranial base and its decreased

flexure cause the nasomaxillary complex to be placed in a more protrusive position relative to the mandible. The decreased cranial base flexure also causes the nasomaxillary complex to be lower relative to the mandibular condyle. The lowered nasomaxillary complex creates a downward and backward rotation of the mandible. As the mandible is rotated downward and backward, the occlusal plane also takes a downward rotation. The forward displacement of the maxilla and the downward rotation of the mandible results in a population tendency toward mandibular retrusive/maxillary protrusive features and a Class II malocclusion.

The typical features of the brachycephalic headform and associated facial pattern are descibed by Enlow (1982). The cranial base is shorter anterior-posteriorly and wider laterally compared to the dolicocephalic. The effective length of the cranial base is shortened further due to an increased cranial base flexure. The more upright middle cranial fossae place the maxilla in a more posterior position relative to the mandible. Because the horizontal length of the nasomaxillary complex is shorter, as established by the foreshortened anterior cranial fossae, and also because the mandible is relatively forward, there is a greater population tendency toward a prognathic profile and Class III

malocclusion. The occlusal plane and mandibular ramus may also be aligned less downward than in dolicocephlics.

The mesocephalic headform is intermediate in cephalic and cranial indices between dolicocephalic and brachycephalic headforms. It is also intermediate for most anatomic relationships (Bhat and Enlow 1985).

The dinaric headform is technically brachycephalic (often hyperbrachycephalic), yet the anterior portion of the skull has many dolicocephalic features. The skull shows occipital or lambdoidal flattening together with either postero-superior calvaria peaking or bilateral parietal bossing (Bhat and Enlow 1985).

As the facial structures are suspended from the basicranium, the facial type is related to the neurocranial configuration. Thus, the dolicocephalic headform usually has a leptoproscopic facial type - long and narrow. The brachycephalic headform has an euryproscopic facial type - short and wide. The dinaric tends to have exaggerated leptoproscopic features. The forehead is sloping, the supraorbital ridges are prominent, and the face tends to be very long vertically and topographically very protrusive with a large, often aquiline nose (Enlow 1982).

Counterpart analysis

The counterpart analysis of Enlow and others (1971a) describes the relationships of anatomical and developmental characteristics that have produced the craniofacial composite pattern in an individual. Unlike conventional cephalometric analyses, planes and angles are used to show how a craniofacial pattern has arisen. Comparisons to population means are not used. The many regional counterpart relationships in the craniofacial complex are assessed and this information is used to interpret the biological basis for the resultant individual morphology. Information on individualized growth processes can be gained from cephalograms without the use of metallic implants, histologic reconstruction or vital staining.

In the counterpart analysis, planes are constructed to represent growth and remodeling fields. Major sites and fields of growth and remodeling mark functional boundaries and identify important locations involving the displacement of whole bones away form each other as they all enlarge in an interrelated manner. The boundaries and sites involved in the counterpart analysis are: the maxillary tuberosity, the mandibular condyle, the ramus-corpus junction, the anterior surfaces of the maxillary and mandibular arches, the posterior part of

the anterior cranial fossa, the occlusal plane and the sphenoethmoidal junction. The PM (posterior maxillary) plane is used as the reference plane because of its anatomic significance. This plane is approximately perpendicular to the line of vision, regardless of the rotational positions of the various other planes. Thus, the PM plane represents a plane that is consistent with the anatomically "neutral" position of the head. The PM plane marks the anatomic junction between the middle and anterior cranial fossa, which importantly, establishes the posterior boundary for the ethmomaxillary field of growth.

Studies on headform and facial pattern

Bhat and Enlow (1985) studied facial variations in Angle Class I and Class II subjects in relation to headform type. They found that "Class I as a discrete and anatomically different type of craniofacial pattern, does not exist." The Class I group contained individuals with various combinations of mandibular retrusive and mandibular protrusive anatomic features, thus demonstrating intrinsic tendencies toward either Class II or Class III depending on the extent of "compensations" occurring during the growth process. Middle cranial fossa (MCF) inclination, ramus orientation, posterior

maxillary vertical height, maxillary and mandibular skeletal arch lengths, ramus width and A/B facial types were studied. In the dolicocephalic and mesocephalic groups there was a significantly high incidence of a mandibular retrusive effect and a much lesser frequency for a mandibular protrusive effect for inclination of the MCF, ramus orientation, relative vertical nasomaxillary length and the relative sizes of the bony arches. The mesocephalic group was intermediate for most anatomic relationship frequencies considered in this study. The dinaric group, which comprises a dolicocephalic type of headform that has undergone brachycephalization, was not intermediate in a manner comparable to the mesocephalic group. Rather, an admixture of strong leptoproscopic facial features are combined with euryproscopic characteristics to yield an essentially separate craniofacial group.

Bhat and Enlow (1985) showed the frequency of anterior and posterior inclination of the middle cranial fossa (MCF) to differ according to the headform group. The following information is based on their study. Dolicocephalics had a greater frequency of anteriorly inclined MCF (mandibular retrusive effect) and less frequency of posteriorly inclined MCF (mandibular protrusive effect) than brachycephalics. The mesocephalic group showed frequencies intermediate

between these two groups. The dinaric group had the highest frequency for a posteriorly inclined MCF (mandibular protrusive effect) and the lowest frequency for an anteriorly rotated MCF (mandibular retrusive effect) of all the groups.

The orientation of the ramus showed varying population frequencies according to headform group. The dolicocephalic group showed a higher frequency of mandibular retrusive orientation and a lower frequency of mandibular protrusive orientation than the brachycephalic group. The mesocephalic group demonstrated frequencies of mandibular retrusive orientation and mandibular protrusion orientation intermediate between the dolicocephalic and brachycephalic groups, whereas the dinarics showed fewer retrusive tendencies than the dolicocephalics, but also a lesser protrusive distribution than the brachycephalics, thus reflecting their composite craniofacial form.

The relative posterior maxillary vertical height (the height of the nasomaxillary complex compared to the combined heights of the ramus and middle endocranial fossa) tends to vary according to headform type. Dolicocephalics show a greater frequency for a relatively long posterior maxillary height (mandibular retrusive effect) and a lesser frequency of a relatively short posterior maxillary vertical height than brachycephalics.

The mesocephalic group also tends toward a relatively long posterior maxillary height (mandibular retrusive effect). The dinaric group had the highest incidence of all groups for a vertically long midface.

Dolicocephalic, mesocephalic and dinaric groups showed a greater frequency for a short mandibular arch than the brachycephalic group.

Compensatory mechanisms (as described by Enlow et al. 1971b) were observed in the ramus width of different headforms. Overall, dolicocephalics, mesocephalics and dinaric groups showed a composite of features with a mandibular retrusive effect yet the incidence of a broad ramus (mandibular protrusive effect) was higher in the dolicocephalic and dinaric groups and more narrow in the brachycephalic group which has the highest incidence of the various mandibular protrusive features. The development of the ramus and associated soft tissues, thus, is seen to function in a compensatory role in many individuals. Dolicocephalic and mesocephalic headforms show a greater composite of mandibular retrusive features which results in a greater incidence of "A" type or mandibular retrusive faces (Class I and Class II) and the lowest incidence of "B" type faces than in both the brachycephalic and dinaric groups. The brachycephalic group had the highest incidence of B type or mandibular protrusive faces (Class I and Class II) and the lowest

incidence of A type faces. The dinaric group had a high frequency of posterior MCF inclination (mandibular retrusive effect) and a high frequency of a relatively long (vertical) midface. This group had more B types than the dolicocephalic group and more A types than the brachycephalic group.

Enlow, Kuroda and Lewis (1971a) studied the Class III malocclusion utilizing the counterpart analysis. Sixty-six percent were seen to have a MCF/PM alignment, thus contributing a basicranial factor to the mandibular protrusive relationship, while only 25 percent show an opposite maxillary protrusion effect. Sixty-two percent had a forward aligned ramus (mandibular protrusive), while 34 percent demonstrated a backward aligned ramus (maxillary protrusive). The Class III group exhibited the same reciprocal relationship between ramus size (separate from ramus alignment) and the anteroposterior middle cranial floor dimension as the Class I and Class II groups, thus providing a degree of compessation for the mandibular protrusive/retrusive nature of the basicranium. A backward aligned cranial floor was compensated by a more narrow ramus while a forward aligned cranial floor had a compensatory wider ramus. Seventy percent have a downward corpus and occlusal alignment (mandibular protrusive), and 21 percent have an opposite maxillary protrusive alignment. Class III

individuals tend to have a short midface appearance and overbite, and a short PM vertical. A high percentage of Class III individuals show a long mandibular corpus and dental arch relative to the maxillary bony and dental arches (dentally - 53% long, 32% short; skeletally - 87% long, 9% short). The ramus/corpus angle is open thus lengthening overall the mandible (Enlow 1982). The face appears vertically long because the lower face is elongate in contrast to the Class II in which it is the nasomaxillary complex that is vertically elongate. While the "mandibular plane" may appear "steep", it is a more open ramus/corpus angle that produces it in contrast to a steep Class II angle caused by a whole mandible downward/ backward rotation resulting from the long midface (Enlow 1982).

Pfister (1983) classified Class III facial types in his morphometric study. He also found that the most stable Class III anatomic parts were the middle cranial fossa alignment and the mandibular corpus length relative to the maxilla. The most variable arrangements were the ramus alignment and horizontal width of the ramus relative to the middle cranial fossa dimension.

As evidenced by the literature, the Class III pattern is not fully understood. Further study is needed to identify the developmental growth processes leading to the Class III pattern.

STATEMENT OF THESIS

The objective of this study is to determine the composite of regional anatomic relationships that underlie the Class III malocclusion pattern in the dolichocephalic headform. The Class III malocclusion pattern in the dolichocephalic headform has not been previously studied. The dolichocephalic headform is most commonly regarded as having regional mandibular retrusive relationships. Leptoproscopic features and Class II rather than Class III tendencies typically characterize this headform.

MATERIALS AND METHODS

Lateral cephalometric radiographs were obtained from the Bolton-Brush collections housed at Case Western Reserve University, Case Western Reserve University Orthodontic Department as well as from the records of a private practioner.

Sample

Individuals of various ages were included in this study. The mean age of the total sample was 15.2 years with a range of 6-41 years of age. The sample was subdivided into three broad groups which are described later.

An important factor is that, for the purpose of the study, the control sample for the Caucasian groups was restricted to Class I B types. A B type is defined as having B point anterior to A point when measured on the functional occlusal plane. This group was used because of its Class III tendencies rather than the Class II tendencies which characterize the A type (A point protrusive). Class I B types and the Class III have many of the same underlying anatomic characteristics and differ either according to the number or the magnitude of regional mandibular protrusive effects. Since the Class I B and Class III types make up a range of individuals with mandibular protrusive tendencies, the samples selected

necessarily had a spread of overlapping features. The differences seen between these groups thus reflect how far apart in the range the two samples are. Had the Class III sample been compared to a Class I A sample, more dramatic differences would be expected to be seen.

The Class I Afro-American dolichocephalic and mesocephalic samples contained individuals with bimaxillary protrusion having a range of both A and B types. Both groups were selected because many of the same mandibular protrusive features in the Afro-American population underlie the charateristic bimaxillary protrusive and Class III patterns.

In this study, all hyperbrachycephalics and all brachycephalics with dinaric facial features were included in the dinaric group. The dinaric headform is often hyperbrachycephalic and has exaggerated leptoproscopic features with a tendency toward a vertically long nasomaxillary complex. Recent studies suggest that more than one anatomic type of dinaric form exists (Enlow 1990), but at present a systematic classification of anatomic features has not yet been developed.

Group I

A sample of subjects with Angle Class III occlusion was selected according to the following criteria:

1. No orthodontic treatment prior to or concurrent with each radiograph selected.
2. Class III molar relationship as determined from the lateral cephalometric radiograph.
3. All necessary landmarks readily identifiable.
4. Frontal cephalometric radiograph available or subject available for a head length/breadth measurement.

This group consisted of the following number of subjects according to headform:

11 Dolichocephalic Caucasians
8 Dolichocephalic Afro-Americans
10 Mesocephalic Caucasians
7 Mesocephalic Afro-Americans
18 Brachycephalic Caucasians
7 Dinaric Caucasians

Group II

A sample of subjects with Angle Class I occlusion was selected according to the following criteria:

1. No orthodontic treatment prior to or concurrent with each radiograph studied.
2. Class I molar relationship as determined from the lateral cephalometric radiograph.
3. All necessary landmarks readily identifiable.
4. Frontal cephalometric radiograph available or subject available for a head length/breadth measurement.
5. Class III tendency - ANB = 0 or B type.

This group consisted of the following number of subjects according to headform:

16 Dolichocephalic Caucasians

38 Mesocephalic Caucasians

24 Brachycephalic Caucasians

19 Dinaric Caucasians

Group III

A sample of subjects with Angle Class I bimaxillary protrusion as selected according to the following criteria:

1. No orthdontic treatment prior to or concurrent with each radiograph studied.
2. Class I molar relationship as determined from the lateral cephalometric radiograph.
3. All necessary landmarks readily identifiable.
4. Frontal cephalometric radiograph available or subject available for a head length/breadth measurement.
5. Dentoalveolar bimaxillary protrusion present.

This group consisted of the following number of subjects according to headform:

14 Dolichocephalic Afro-Americans

15 Mesocephalic Afro-Americans

Technical Details

Tracings of all radiographs were made on 0.003 matte acetate tracing paper using a 0.5mm tracing pencil with 2H drawing leads. All tracings were done by the same

investigator. The linear and angular measurements were made using the millimeter scale or Helios vernier scale and a Baume protractor. All bilateral images were averaged.

All radiographs were corrected for magnification using known ML or P+ values or averages for the age in determining headform ratios. Headform was determined by the ratio of (breadth of skull x 100)/(length of skull). Determinations of maximum breadth and length of the skull as well as the cranial and cephalic indices utilized standard anthropometric procedures (Hrdlicka 1952).

Measurements

Eleven anatomic variables were compared and analyzed for each tracing. The variables studied were:

1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A point and B point
2. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr
3. Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment
4. Ramus alignment
5. Ramus/Middle cranial fossa horizontal dimensions

6. Maxillary and mandibular arches, skeletal dimensions, A point compared with B point
7. Maxillary and mandibular arches, skeletal dimensions, Spr compared with IPr
8. Posterior maxilla as compared with ramus/middle cranial fossa vertical dimensions
9. Gonial angle alignment
10. Maxillary nerve/palatal plane alignment
11. Curve of Spee

A brief description of the planes used in the counterpart analysis accompanies Figures 1 and 2. More detailed explanations of the counterpart analysis and measurement procedures for the variables studied can be found in the works of Enlow et al. 1971a and DiGangi 1986. The result of each part-counterpart comparison were recorded as a maxillary protrusive (+; greater than +1.0mm), a neutral (0; -1.0mm to +1.0mm), or a mandibular protrusive (-; less than -1.0mm) effect. Mandibular protrusive and retrusive anatomical relationships are illustrated in Figures 3 and 4.

Gonial angles greater than +1 or -1 standard deviations from the mean according to standards of Riolo et al. 1975 were considered as having a mandibular protrusive or retrusive effect respectively.

Definitions of anatomic landmarks and cephalometric planes which were used are summarized in Tables 1 and 2.

Figure 1. Planes utilized in the counterpart analysis. The middle cranial fossa (MCF) is represented by a line from articulare to the sphenoethmoidal junction. The posterior maxillary plane (PM) is represented by a line through the sphenoethmoidal junction and the most inferior point of the pterygomaxillary fissure. The PM plane marks the anatomic boundary between the middle and anterior basicranial fossae and also the posterior boundary of the nasomaxillary complex.

Ramus alignment is determined by extending a line from articulare to constructed gonion (not shown in Figures 1-4). In Figures 1-4, an oblique ramus line has been drawn to illustrate the rotational changes of the ramus and mandible as a whole. The width of the ramus is measured from the anterior and posterior borders of the ramus along a reference plane (a plane parallel to the functional occlusal plane through articulare). The horizontal dimension of the middle cranial fossa is measured from articulare to the PM line along the reference plane. Bony maxillary arch lengths are measured from A and SPr points to the PM plane along the reference plane. Bony mandibular arch lengths are measured from B and IPr points to the lingual tuberosity along the reference plane. (From Enlow, D. H., DiGangi, D., McNamara, J.A., Mina, M. 1988. An evaluation of the morphogenic and anatomic effects of the functional regulator utilizing the counterpart analysis. Eur. J. Orthod. 10: 192-202)

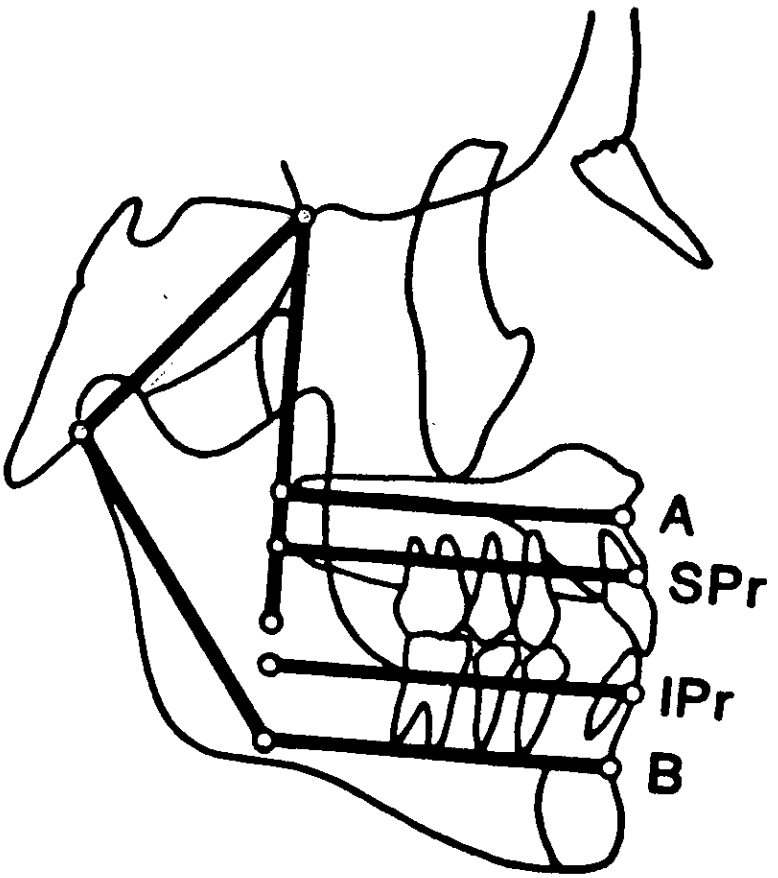

A
SPr
IPr
B

Figure 2. Maxillary nerve/palatal plane alignment. The plane of the maxillary nerve is determined by a line from foramen rotundum in the pterygomaxillary fissure to a point 3mm above orbitale (representing the course of the nerve prior to its downturn into the orbital floor). The palatal plane is determined by drawing a line from ANS to PNS. (From Enlow, D. H., DiGangi, D., McNamara, J.A., Mina, M. 1988. An evaluation of the morphogenic and anatomic effects of the functional regulator utilizing the counterpart analysis. Eur. J. Orthod. 10: 192-202)

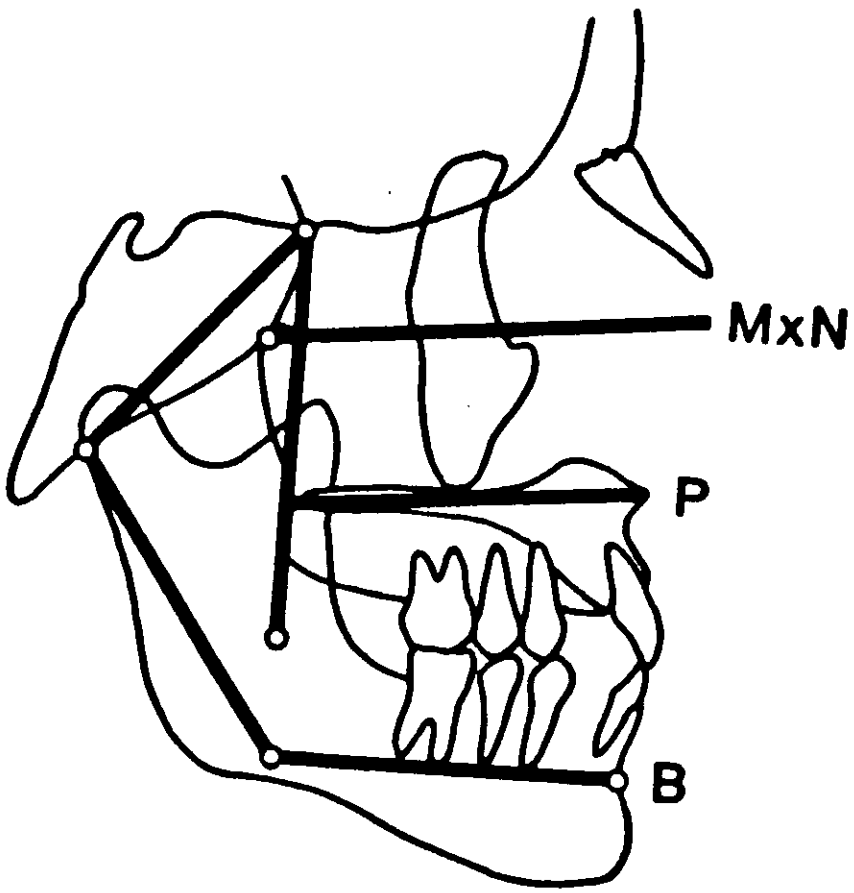

MxN
P
B

Figure 3. Regional mandibular retrusive anatomical relationships. Regional mandibular retrusive effects are seen when there is (a) an anterior inclination of the middle cranial fossa (b) an anteriorly and inferiorly positioned maxillary complex due to the anterior inclination of the middle cranial fossa (c) a downard and backward alignment of the ramus (d) a posterior and inferior positioning of B point due to a backward rotation of the ramus (e) a long nasomaxillary complex (f) an increased width of the middle cranial fossa (MCF) due to an anterior inclination of the MCF. In this figure, an opening of the gonial angle at c would have a mandibular retrusive effect while a closing of the gonial angle would have the opposite effect. (From Enlow, D.H., DiGangi, D., McNamara, J. A., Mina, M. 1988. An evaluation of the morphogenic and anatomic effects of the functional regulator utilizing the counterpart analysis. Eur. J. Orthod. 10: 192-202)

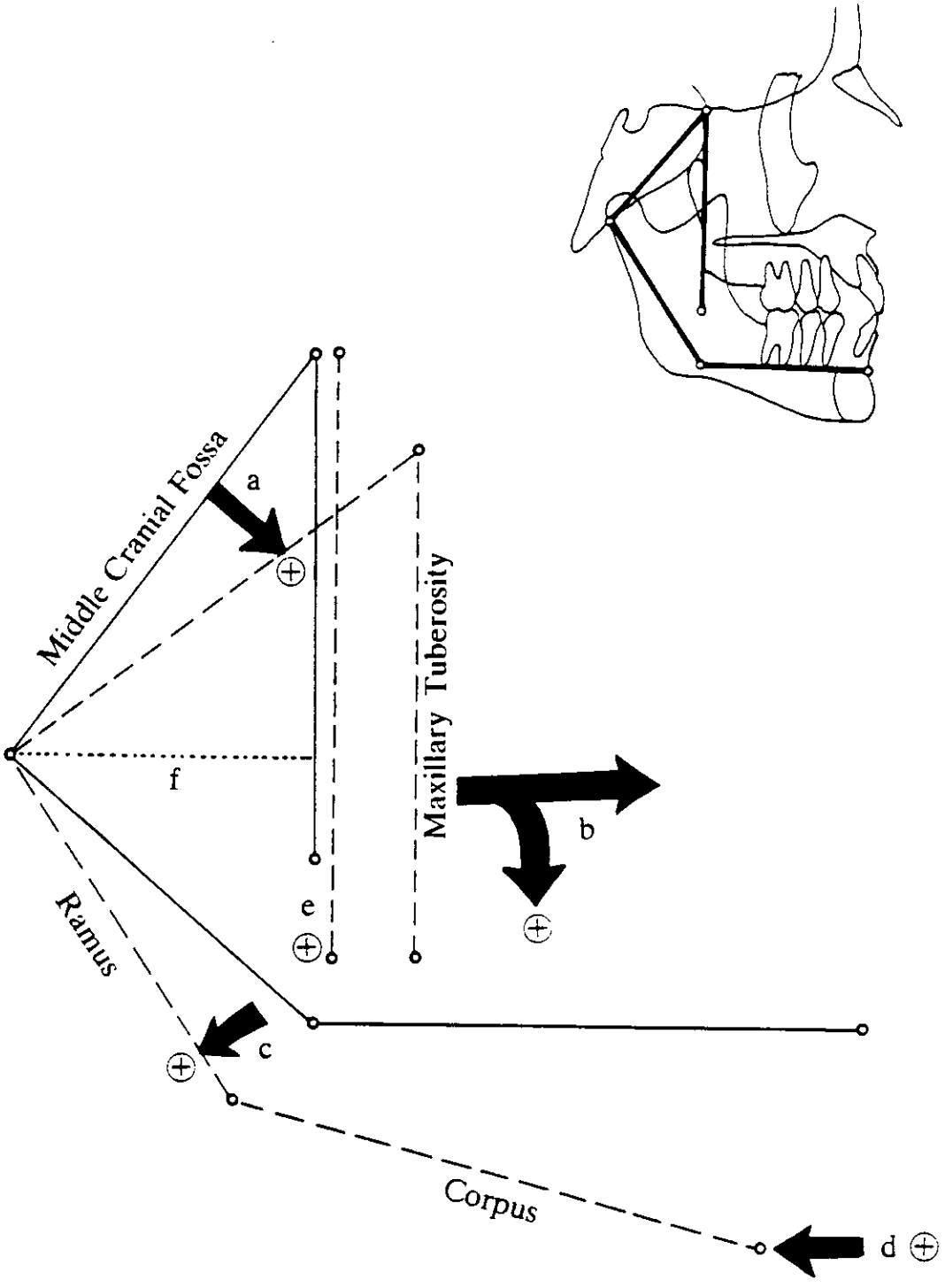
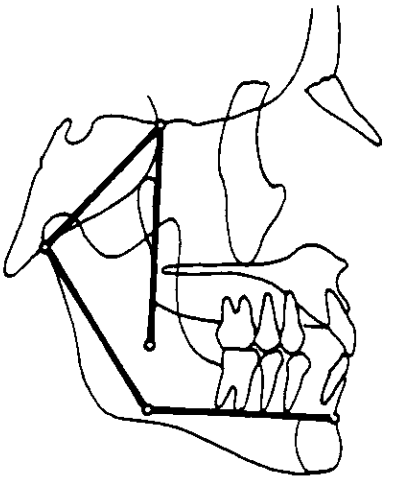

Middle Cranial Fossa
a
Maxillary Tuberosity
b
f
e
Ramus
c
Corpus
d

Figure 4. Regional mandibular protrusive anatomic relationships. Regional mandibular protrusive effects are seen when there is (g) a posteriorly inclined middle cranial fossa (h) a posteriorly and superiorly positioned maxillary due to a posterior inclination of the maxillary complex (j) a forward and upward alignment of the ramus (k) an anteriorly and superiorly positioned B point due to the forward alignment of the ramus (m) a short masomaxillary complex. In this figure, an opening of the gonial angle at j would increase the mandibular protrusive effect while a closing of the gonial angle would have a mandibular retrusive effect. (From Enlow, D.H., DiGangi, D., McNamara, J.A., Mina, M. 1988. An evaluation of the morphogenic and anatomic effects of the functional regulator utilizing the counterpart analysis. Eur. J. Orthod. 10: 192-202)



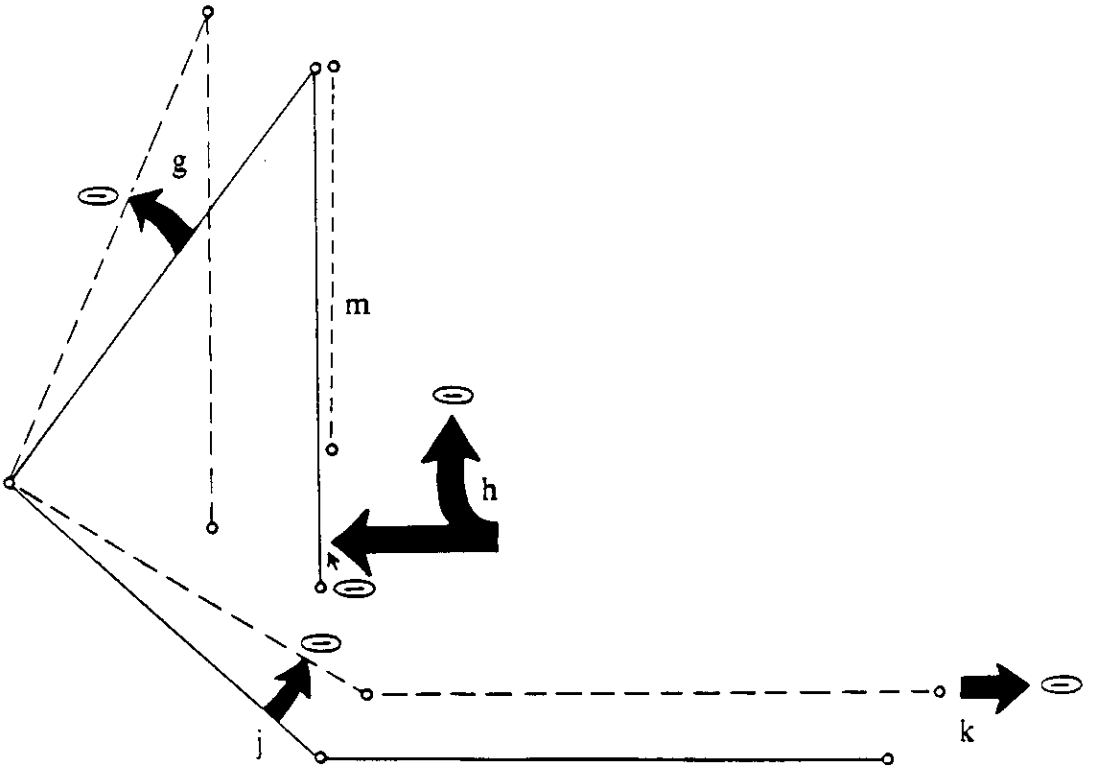

g
m
h
k
j
k

Table 1

DEFINITIONS OF ANATOMIC LANDMARKS

Points	Definition
A	A point, the most posterior point on the labial surface of the premaxilla between anterior nasal spine and superior prosthion.
ANS	Anterior nasal spine, the forward most tip of the nasal side of the palate at the intermaxillary suture.
Ar	Articulare, the point at which the ectocranial surface of the cranial base intersects the posterior margin of the condylar neck.
ARa	Anterior ramus, the point at which the functional occlusal plane intersects the anterior margin of the ramus.
B	B point, the deepest midline point on the mandible between inferior prosthion and pogonion.
Go	Gonion, the intersection of the mandibular plane and a line tangent to the posterior border of the ramus.
IPr	Inferior prosthion, the most anterior point of the tip of the alveolar process between the mandibular central incisors.
Me	Menton, the most inferior point of the symphysis of the mandible.
Or	Orbitale, the lowest point on the inferior margin of the orbit.
PNS	Posterior nasal spine, a process formed by the united, projecting median ends of the posterior borders of the two palatine bones.
PRa	Posterior ramus, the point at which the functional occlusal plane intersects the posterior margin of the ramus.

Table 1 continued

Points	Definition
SE	Sphenoethmoidal junction, the point at which the floor of the anterior cranial fossa intersects the averaged image of the great wings of the sphenoid bone.
Spr	Superior prosthion, the most anterior point of the alveolar portion of the premaxilla, between the maxillary central incisors.

Table 2

DEFINITIONS OF CEPHALOMETRIC PLANES

Planes	Definition
Ar to Go	The line connecting articulare with constructed gonion is used to demonstrate the alignment of the ramus.
ARa	Anterior ramus plane, demonstrated by a line from the intersection of FOP and the anterior border of the ramus drawn parallel to PRa up to REF.
FOP	Functional occlusal plane, a straight line (disregarding any dentoalveolar curve which may be present) drawn from the most anterior maxillary-mandibular premolar contact to the most posterior maxillary-mandibular molar contact using only fully erupted teeth.
MCF	Middle cranial fossa, represented by a line from SE to Ar.
NRa	Neutral ramus alignment, demonstrated by a dashed line drawn from Ar to a point midway between Ar and the neutral PM line at the level of gonion.
PM	PM vertical, a line from SE through the averaged inferior most point of the pterygomaxillary fissure.
PMN	Plane of the maxillary nerve, demonstrated by a line projecting anteriorly from foramen rotundum to a point 3mm superior to the averaged orbitale (Enlow 1982).
PRa	Posterior ramus plane, demonstrated by the line from Ar to the intersection of FOP with the posterior border of the ramus.
REF	Reference line, demonstrated by the line from Ar parallel to FOP.

Statistical Methods

The means, standard deviations and frequency distributions for the eleven variables in each group were calculated. The Mann-Whitney Test, an unpaired, nonparametric significance test for independent samples, was used between pairs of groups. The Kruskal-Wallis Method, a nonparametric analysis of variance for independent samples by randomization, was used when three or more groups were compared.

Analysis of Error

Tracing, plane construction and measuring error were evaluated by retracing 10 lateral cephalometric radiographs chosen at random from the sample, performing the counterpart analysis on each retraced radiograph and comparing the results of the new measurements with the original measurements. The standard error was determined by the equation: $SE = \sqrt{\frac{d^2}{2n}}$

The standard error was determined to be less than or equal to 0.5mm for all variables except arch lengths and gonial angle. For the variables arch length measured at A and B points, the standard error was 0.8mm. At SPr and IPr, the standard error was 0.7mm. The standard error for gonial angle measurement was 0.3 degrees. The averaged absolute differences for MCF alignment, ramus alignment,

PM vertical, aggregate at SPr and IPr, maxillary nerve/palatal plane and curve of Spee were less than 0.5mm. Average differences for gonial angle measurements were 0.2 degrees. Ramus width, aggregate at A and B and arch length measurements averaged less than or equal to 1.0mm. Theoretically, errors should occur in either a positive or negative direction with equal frequency. The averaged absolute differences were not greater than the standard deviation for any group variable. When figuring percentages of positive, negative and neutral effects, a neutral value was defined at $\pm$ 1.0mm taking into account measurement and tracing error.

RESULTS

Descriptive Statistics

Means, standard deviations, minimum and maximum values, and distribution percentages are listed by variable for each group in Tables 3-24.

1. Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at A point and B point

(see Tables 3 and 4)

All Class III groups had a mandibular protrusive composite effect with B point anterior to A point. Of the Class I Caucasian groups, all but the dinaric group also had a total composite mandibular protrusive effect (B type). The Class I Afro-American groups contained A and B type individuals .

TABLE 3

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT A AND B POINTS

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	-11.9	3.3	-16.0	-5.9
III Dolicho A	8	-10.4	2.5	-15.2	-7.1
III Meso C	10	-9.8	3.4	-16.3	-4.3
III Meso A	7	-14.0	2.8	-19.5	-11.7
III Brachy C	18	-11.3	3.5	-17.7	-4.9
III Dinaric C	7	-13.3	5.0	-22.7	-6.0
I Dolicho C	16	-7.5	2.6	-11.8	-2.3
I Dolicho A *	14	-1.2	4.3	-7.0	10.5
I Meso C	38	-7.7	2.5	-12.2	-2.1
I Meso A *	15	-4.0	4.6	-11.4	3.8
I Brachy C	24	-7.4	2.5	-12.9	-2.5
I Dinaric C	19	-4.5	3.5	-12.5	0.0

TABLE 4

DISTRIBUTION PERCENTAGES FOR AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT A AND B POINTS

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	100	....	....
III Dolicho A	100	....	....
III Meso C	100	....	....
III Meso A	100	....	....
III Brachy C	100	....	....
III Dinaric C	100	....	....
I Dolicho C	100	....	....
I Dolicho A	14	43	43
I Meso C	100	....	....
I Meso A	80	13	7
I Brachy C	100	....	....
I Dinaric C	89	11	....

2.Aggregate cranial floor/maxilla and ramus/corpus horizontal dimensions at SPr and IPr

(see Tables 5 and 6)

All Class III groups had a composite mandibular protrusive effect. The Class I groups showed varying degrees of mandibular protrusion and retrusion when measured at SPr and IPr .

TABLE 5

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS HORIZONTAL DIMENSIONS AT SPr AND IPr

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dol[illegible]ho C	11	-8.4	2.8	-13.6	-5.0
III Dolicho A	8	-7.2	1.9	-10.2	-4.2
III Meso C	10	-6.5	2.3	-11.1	-3.5
III Meso A	7	-9.7	2.0	-11.8	-7.0
III Brachy C	18	-7.8	2.2	-12.6	-4.0
III Dinaric C	7	-7.6	3.2	-13.4	-2.7
I Dolicho C	16	-3.6	1.5	-5.9	-1.1
I Dolicho A *	14	0.8	2.7	-3.4	5.2
I Meso C	38	-4.0	1.7	-7.8	0.0
I Meso A *	15	-1.0	3.2	-7.0	3.5
I Brachy C	24	-4.3	2.0	-11.9	-1.0
I Dinaric C	19	-1.7	2.6	-7.7	1.7

TABLE 6

DISTRIBUTION PERCENTAGES FOR AGGREGATE CRANIAL FLOOR/MAXILLA AND RAMUS/CORPUS DIMENSIONS AT SPr AND IPr

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	100	....	....
III Dolicho A	100	....	....
III Meso C	100	....	....
III Meso A	100	....	....
III Brachy C	100	....	....
III Dinaric C	100	....	....
I Dolicho C	100	....	....
I Dolicho A	21	21	57
I Meso C	92	8	....
I Meso A	40	33	27
I Brachy C	96	4	....
I Dinaric C	53	32	16

3.Middle cranial fossa (MCF) and posterior maxillary (PM) relative alignment

(see Tables 7 and 8)

Caucasian Groups

In the Class III dolichocephalic group, a little more than half (55%) had a posterior (more upright) MCF inclination contributing to a mandibular protrusive effect. Thirty-six percent had an opposite, anteriorly inclined MCF contributing a regional mandibular retrusive effect. The brachycephalic Class III showed an even spread of individuals with approximately one-third having a posteriorly inclined MCF, one-third with an anteriorly inclined MCF and one-third neutral.

The Class I B type and the Class III dolichocephalic were found to be essentially similar for MCF alignment. Class I B type dolichocephalics were seen to have a slightly lower frequency of MCF mandibular protrusive effects and a slightly higher frequency of mandibular retrusive effects than the Class III dolichocephalics.

Class I B type brachycephalics essentially showed the same frequency for mandibular retrusive and mandibular protrusive MCF relationships as the Class III brachycephalic group.

For Class I B types, dolichocephalics and brachycephalics showed similar frequencies for mandibular protrusive MCF effects, although the dolichocephalic

group had somewhat fewer neutral effects and greater mandibular retrusive effects than brachycephalics. In general, however, dolichocephalic-brachycephalic Class I/Class I and Class III/Class III comparisons are analogous.

The dinaric Class III group had frequency distributions essentially identical to the Class I dinaric group for MCF relationships. Among all of the different Class I headform types, the dinarics had the highest frequency of posterior inclination and the lowest frequency for anterior inclination of the MCF. The dinaric Class III groups showed the highest frequency of a posteriorly inclined MCF of all the headform types, although the percentage is closest to the dolichocephalics. This Class III group also had a lower frequency of anterior MCF inclination than the dolichocephalics and brachycephalics.

The mesocephalic Class III group showed the highest frequency of a neutral MCF alignment (70%), contributing also in the lowest frequencies of resultant mandibular retrusive and mandibular protrusive effects in the class III groups. Class I B mesocephalics had the lowest frequency of mandibular protrusive MCF alignment and the highest frequency of neutral and mandibular retrusive MCF alignment.

Afro-American Groups

Afro-American individuals showed a strong tendency (67-86%) toward anteriorly inclined middle cranial fossa in all groups.

TABLE 7

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR MIDDLE CRANIAL FOSSA AND POSTERIOR MAXILLARY RELATIVE ALIGNMENT

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	-0.6	2.7	-4.5	2.8
III Dolicho A	8	2.8	2.8	-1.2	8.1
III Meso C	10	-0.3	1.2	-2.2	1.8
III Meso A	7	1.8	2.5	-2.7	4.6
III Brachy C	18	-0.1	2.0	-3.1	3.0
III Dinaric C	7	-1.0	2.6	-3.2	3.8
I Dolicho C	16	-0.3	3.0	-5.5	5.8
I Dolicho A *	14	3.0	1.8	-0.5	5.6
I Meso C	38	0.6	2.8	-6.2	6.2
I Meso A *	15	2.3	2.6	-2.9	6.5
I Brachy C	24	-0.3	2.3	-4.2	4.3
I Dinaric C	19	-1.2	2.7	-5.2	4.7

TABLE 8

DISTRIBUTION PERCENTAGES FOR MIDDLE CRANIAL FOSSA AND POSTERIOR MAXILLARY RELATIVE ALIGNMENT

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	55	9	36
III Dolicho A	13	13	75
III Meso C	20	70	10
III Meso A	14	14	71
III Brachy C	39	33	28
III Dinaric C	57	29	14
I Dolicho C	44	13	44
I Dolicho A	....	14	86
I Meso C	21	32	47
I Meso A	13	20	67
I Brachy C	42	25	33
I Dinaric C	58	26	16

4.Ramus alignment

(see Table 9 and 10)

Caucasian Groups

Class III dolichocephalics were seen to have an equal distribution of mandibular retrusive (45%) and mandibular protrusive (45%) ramus alignment effects. Brachycephalics and dolichocephalics had an equal frequency of a forward (mandibular protrusive) ramus. A neutral ramus alignment was seen twice as often as a mandibular retrusive ramus alignment in the brachycephalic group. A backward (mandibular retrusive) alignment was seen almost three times more frequently in the dolichocephalic Class III than in the brachycephalic Class III.

The dolichocephalic Class III group had a much higher frequency of a forward, protrusive-effect ramus alignment than the Class I B dolichocephalic group. Conversely, the Class I B group had a higher frequency for a neutral ramus alignment than the Class III group. Thus, in the Class III dolichocephalic, ramus alignment is often a contributing factor in mandibular protrusion.

Class III brachycephalics also have a higher frequency of a ramus alignment with a mandibular protrusive effect than their Class I B counterpart. This also results in lower frequencies of neutral and mandibular retrusive ramus alignments in the Class III group. Here too, ramus alignment is a contributing factor in the Class

III pattern.

Class I B dolichocephalics had a somewhat greater trend toward a mandibular retrusive ramus alignment while the trend for the Class I B brachycephalic group was toward more neutral values, thus weighing the latter more away from any mandibular retrusive tendency.

Class III dinarics had the highest frequency of a forward aligned ramus than any other group. This frequency was almost four times higher than in the Class I B dinaric group. The frequency distribution in the Class III dinaric was half as great as the Class I B dinaric for neutral and mandibular retrusive ramus effects. Ramus alignment thereby represents a strong contributing factor in the Class III pattern for the dinaric.

The frequency distribution for ramus alignment in the Class III dinarc was not similar to the Class III dolichocephalic, brachycephalic or mesocephalic. The percentages in the Class I B dinaric and and Class I B dolichocephalic were identical. The Class I B dinaric had a slightly greater tendency toward mandibular retrusive effects than the mesocephalic or brachycephalic Class I B groups.

The mesocephalic Class III had a lower frequency of mandibular protrusive effects and a greater frequency of neutral effects than the other Class III groups. The mesocephalic Class III and Class I B groups had similar

frequency distributions for ramus alignment with a slight shift in the Class I B group from less neutral to a more mandibular retrusive frequency. The Class I B mesocephalic group was almost identical to the brachycephalic frequency distribution. In this study, a forward and upward aligned ramus does not seem to be a significant factor contributing to a Class III pattern in the Class III mesocephalic.

Afro-American Groups

The Afro-American groups show the highest frequency distributions (75-100%) for a backward and downward aligned ramus (mandibular retrusive). None of these groups were seen to have a forward aligned ramus. The mandibular retrusive ramus alignment trend in the Afro-American groups is opposite to the more neutral or mandibular protrusive tendency seen in Caucasians.

TABLE 9

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR RAMUS ALIGNMENT

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	-0.2	3.2	-6.7	5.0
III Dolicho A	8	3.5	3.1	0.5	10.5
III Meso C	10	-0.2	1.8	-3.5	2.7
III Meso A	7	3.8	2.9	1.1	8.4
III Brachy C	18	-1.0	2.1	-5.3	2.0
III Dinaric C	7	-1.4	3.0	-5.0	3.4
I Dolicho C	16	2.1	2.7	-2.7	5.8
I Dolicho A *	14	5.5	2.4	0.0	9.4
I Meso C	38	0.1	2.2	-5.6	4.6
I Meso A *	15	4.7	3.1	0.0	9.3
I Brachy C	24	0.1	1.8	-4.1	3.7
I Dinaric C	19	1.6	2.4	-1.8	6.0

TABLE 10

DISTRIBUTION PERCENTAGES FOR RAMUS ALIGNMENT

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	45	9	45
III Dolicho A	....	25	75
III Meso C	20	60	20
III Meso A	....	....	100
III Brachy C	44	39	17
III Dinaric C	57	14	29
I Dolicho C	13	38	50
I Dolicho A	....	7	93
I Meso C	24	45	32
I Meso A	....	20	80
I Brachy C	21	50	29
I Dinaric C	16	32	52

5.Ramus/MCF horizontal dimensions

(see Tables 11 and 12)

Caucasian Groups

Over half in the Class III dolichocephalic sample had a narrow ramus, showing a degree of compensation for the Class III pattern. Only 27 percent had a wide ramus contributing to the Class III development. The Class III brachycephalic group had an even lower frequency for a wide ramus (6%). Sixty-one percent of the brachycephalics had a narrow, compensating-type of ramus.

The Class I B dolichocephalic group showed a larger percentage with a wide ramus than the Class III group, yet the frequency for a narrow ramus was about the same for both groups. A higher degree of compensation was thus seen in the Class III group.

Percentages of neutral, protrusive and retrusive effects were very similar in the Class III and Class I B brachycephalic groups, showing a large percentage with mandibular retrusive effects.

Class I B dolichocephalics and brachycephalics were seen to have the same frequency of mandibular retrusive effects (50%), yet frequency distributions for neutral and mandibular protrusive relationships were opposite. A mandibular protrusive relationship was seen in the Class B dolichocephalic in 44% of the sample and a neutral relationship was seen in 6% of the sample. Reversing

these distributions, there is a mandibular protrusive effect in 8% of the sample in the Class I B brachycephalic and a neutral relationship in 38% of the sample. Even in the Class I B groups, there may be an attempt for the ramus to compensate for other mandibular retrusive or protrusive relationships present in the individual.

The highest frequency for a narrow ramus was seen in the Class III mesocephalic group. No individuals in this group were seen to have a wide ramus. The dinaric Class III group had very similar frequency distributions to the mesocephalic group yet it had slightly higher percentages for a neutral ramus width.

Class I B and Class III dinarics had roughly the same percentage of a more narrow ramus, but the Class I B group had a larger percentage with a wider ramus.

The dinaric Class III was fairly similar to the Class III brachycephalic group with a predominance of mandibular retrusive effects. The Class I dinaric group was also fairly similar to the Class I brachycephalic group, with a predominance of mandibular retrusive effects.

Afro-American Groups

In the Afro-American dolichocephalic and mesocephalic Class I and III groups, there is a strong tendency (60-100%) toward a wide ramus.

TABLE 11

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR RAMUS/MIDDLE CRANIAL FOSSA HORIZONTAL DIMENSIONS

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	1.2	4.0	-4.6	8.6
III Dolicho A	8	-4.7	6.1	-16.5	2.7
III Meso C	10	2.2	1.7	0.0	4.7
III Meso A	7	-2.9	3.3	-7.8	2.7
III Brachy C	18	2.3	2.6	-1.4	7.8
III Dinaric C	7	2.9	2.0	0.0	5.3
I Dolicho C	16	-0.3	4.2	-8.7	5.8
I Dolicho A *	14	-4.7	2.1	-9.0	-1.1
I Meso C	38	0.8	2.9	-7.0	6.5
I Meso A *	15	-3.5	4.0	-9.0	-1.1
I Brachy C	24	2.4	3.4	-5.3	8.0
I Dinaric C	19	1.9	3.4	-4.6	9.7

TABLE 12

DISTRIBUTION PERCENTAGES FOR RAMUS/MIDDLE CRANIAL FOSSA HORIZONTAL DIMENSIONS

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	27	18	55
III Dolicho A	63	25	13
III Meso C	....	20	80
III Meso A	86	....	14
III Brachy C	6	33	61
III Dinaric C	....	29	71
I Dolicho C	44	6	50
I Dolicho A	100	....	....
I Meso C	18	45	37
I Meso A	60	33	7
I Brachy C	8	38	54
I Dinaric C	21	11	68

6.Maxillary/mandibular arches

(see Tables 13, 14, 15 and 16)

Caucasian Groups

All Caucasian Class III headform groups had consistently (100%) long mandibular arch lengths (mandibular protrusive) relative to the maxillary arch when measured at points A and B and SPr and IPr points. Class I groups had a 90-100% frequency of mandibular protrusive effects when measured at points A and B. When arch lengths were measured at SPr and IPr, all Class I headform groups also had a sizeable majority of frequencies for mandibular protrusive effects.

Afro-American Groups

Measuring at points A and B, the Class III dolichocephalic group all had long mandibular arches. The Class III mesocephalic group contained 88% with long mandibular arches. The Class I groups contained varying frequencies for mandibular protrusive and retrusive effects in arch length as these groups contained A as well as B type individuals.

TABLE 13

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS, A POINT COMPARED WITH B POINT

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	-12.7	4.4	-18.8	-4.9
III Dolicho A	8	-8.9	5.0	-16.4	0.6
III Meso C	10	-12.0	4.0	-16.5	-3.7
III Meso A	7	-13.1	3.4	-19.5	-9.6
III Brachy C	18	-13.9	4.7	-23.8	-6.3
III Dinaric C	7	-15.5	4.4	-22.9	-8.7
I Dolicho C	16	-7.6	4.1	-15.0	-1.2
I Dolicho A *	14	0.4	4.7	-5.4	11.4
I Meso C	38	-9.6	4.0	-17.9	-1.4
I Meso A *	15	-3.3	6.2	-14.0	7.8
I Brachy C	24	-10.1	4.5	-23.3	-3.8
I Dinaric C	19	-6.0	5.1	-20.6	1.4

TABLE 14

DISTRIBUTION PERCENTAGES FOR MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS, A POINT COMPARED WITH B POINT

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	100	....	....
III Dolicho A	88	13	....
III Meso C	100	....	....
III Meso A	100	....	....
IIII Brachy C	100	....	....
III Dinaric C	100	....	....
I Dolicho C	100	....	....
I Dolicho A	43	7	50
I Meso C	100	....	....
I Meso A	67	13	20
I Brachy C	100	....	....
I Dinaric C	90	5	5

TABLE 15

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS, SPr COMPARED WITH IPr

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	-8.9	3.5	-14.2	3.3
III Dolicho A	8	-5.7	5.3	-11.5	2.6
III Meso C	10	-8.5	2.9	-11.9	-3.2
III Meso A	7	-9.2	3.9	-14.8	-2.6
III Brachy C	18	-10.5	3.8	-18.8	-4.6
III Dinaric C	7	-9.9	2.8	-14.0	-5.4
I Dolicho C	16	-3.1	3.4	-9.0	1.3
I Dolicho A *	14	2.6	3.5	-4.2	6.6
I Meso C	38	-5.9	3.4	-13.0	1.9
I Meso A *	15	-0.3	5.2	-8.3	8.5
I Brachy C	24	-7.1	3.7	-15.5	0.0
I Dinaric C	19	-3.1	4.3	-13.5	4.1

TABLE 16

DISTRIBUTION PERCENTAGES FOR MAXILLARY/MANDIBULAR ARCHES, SKELETAL DIMENSIONS, SPr COMPARED WITH IPr

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	100	....	....
III Dolicho A	75	....	25
III Meso C	100	....	....
III Meso A	100	....	....
III Brachy C	100	....	....
III Dinaric C	100	....	....
I Dolicho C	63	31	6
I Dolicho A	14	21	64
I Meso C	89	8	3
I Meso A	33	27	40
I Brachy C	92	8	....
I Dinaric C	68	16	16

7.Posterior maxillary vertical dimension

(see Tables 17 and 18)

Caucasian Group

A short posterior maxillary vertical dimension (PM) has a mandibular protrusive effect because it allows the ramus to be aligned in a more forward position. The dolichocephalic Class III group has a frequency distribution of about one-third of the sample with a short PM vertical, thus contributing to the Class III pattern. The brachycephalic Class III group also has an approximately one-third distribution with a short PM length. The distribution of neutral and mandibular retrusive effects in each group, however, is reversed. About one-half of the dolichocephalic group has a long (mandibular retrusive) PM vertical. One-half of the brachycephalics have a neutral PM vertical. The dolichocephalic Class III thus has a lesser tendency as a group for the PM to contribute the protrusive relationship. This is consistent with the "long-faced" tendency for dolichocephalics.

The Class III dolichocephalic has almost a three times greater frequency of a short PM vertical than the Class I B dolichocephalic. Further, the Class III group has about a third less frequency of a long PM than the Class I B group. The greater tendency toward a short PM vertical contributes to the Class III pattern.

A lower frequency of a short or neutral PM dimension

is seen in the Class I B brachycephalic than in the Class III brachycephalic, thus augmenting mandibular protrusion in the brachycephalic Class III's.

Class I B dolichocephalics have the highest frequency for a long PM vertical of all the headform groups. The Class I B brachycephalic has a slightly higher PM frequency for a mandibular protrusive effect than the dolichocephalic. The shift in the brachycephalic is toward a neutral PM dimension.

The highest frequency for a short PM vertical dimension is seen in the Class III dinaric group. This is in contrast to the Class I B dinaric which has the lowest frequency for a short PM. The Class I B group has approximately twice the frequency for a long PM as the Class III. Class I B dinarics have similar percentages of retrusive, neutral, and protrusive effects as the Class I B dolichocephalics. Thus, both the dinaric and dolichocephalic Class I groups are showing the typical "long-faced" features normally associated with these headforms.

The mesocephalic Class III and Class I B groups have identical frequency distributions for the PM vertical dimension. The Class III group is intermediate in frequencies to the Class III dolichocephalic and brachycephalic groups. The highest frequency in the Class I B groups for a short PM is found in the mesocephalic group. The Class I mesocephalic group is intermediate to the dolicho-

cephalic and brachycephalic in frequency for a neutral PM length. Similar mandibular retrusive frequencies are seen for the Class I B mesocephalic and brachycephalic.

In this study, the Class III dinaric showed the highest frequency of a short PM vertical length.

Afro-American Groups

The dolichocephalic and mesocephalic groups were found to have high percentages of long PM vertical dimensions. Class III dolichocephalic Afro-Americans and Caucasians had identical frequency distributions for PM length. Class I B dolichocephalic Caucasians, Class I dolichocephalic Afro-Americans and Class I mesocephalic Afro-Americans all had similar frequency distributions with a strong tendency toward a long PM vertical dimension.

TABLE 17

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR PM AS COMPARED WITH RAMUS/MCF VERTICAL DIMENSIONS

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	0.5	3.3	-4.3	3.9
III Dolicho A	8	0.7	3.2	-3.7	5.7
III Meso C	10	0.1	2.2	-2.8	3.6
III Meso A	7	2.0	2.3	-1.0	4.9
III Brachy C	18	-0.9	3.0	-7.5	4.0
III Dinaric C	7	-0.4	2.0	-2.2	3.4
I Dolicho C	16	2.2	3.3	-3.8	9.0
I Dolicho A *	14	2.4	3.2	-4.0	6.6
I Meso C	38	-0.3	3.3	-7.1	7.6
I Meso A *	15	2.5	3.8	-6.5	6.6
I Brachy C	24	0.4	2.7	-6.6	5.2
I Dinaric C	19	2.8	3.8	-4.7	9.4

TABLE 18

DISTRIBUTION PERCENTAGES FOR POSTERIOR MAXILLA COMPARED WITH RAMUS/MIDDLE CRANIAL FOSSA VERTICAL DIMENSIONS

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	36	9	55
III Dolicho A	38	13	50
III Meso C	40	30	30
III Meso A	....	29	71
III Brachy C	33	50	17
III Dinaric C	57	14	29
I Dolicho C	13	13	75
I Dolicho A	14	14	71
I Meso C	42	24	34
I Meso A	13	20	67
I Brachy C	21	42	38
I Dinaric C	11	21	68

8.Gonial angle

(see Tables 19 and 20)

Caucasian Group

As the gonial angle becomes larger, the effective length of the mandible is increased thus providing a mandibular protrusive effect.

Thirty-six percent of the Class III dolichocephalic sample had an increased gonial angle causing a mandibular protrusive effect. The other 64% had a gonial angle which was considered neutral. The brachycephalic Class III group had a higher frequency of an increased gonial angle (56% protrusive; 44% neutral) than the dolichocephalic group. Neither group was found to have a gonial angle producing a mandibular retrusive effect.

The dolichocephalic Class I B group showed half of the sample with neutral gonial angle, 25% mandibular protrusive and 25% mandibular retrusive. Class III dolichocephalics had a slightly greater tendency toward an increased gonial angle contributing to the Class III pattern.

The Class I B brachycephalic group showed a greater tendency toward neutral and decreased gonial angles as compared to the Class III brachycephalics.

Class I B dolichocephalic and brachycephalic groups showed somewhat similar percentage distributions with half having a neutral gonial angle. The brachycephalic

group had a higher percentage of increased gonial angles and a lower percentage of decreased gonial angles than the dolichocephalic group.

The Class III dinaric group had the highest frequency of an open gonial angle (71%) while the Class I dinaric group had the lowest frequency for an open gonial angle. The Class III group did not have any individuals with a neutral gonial angle but did contain 29% with a decreased gonial angle (mandibular retrusive). The Class I dinaric group consisted mainly of individuals with neutral gonial angles (58%). The Class I B and III groups had equal frequencies for decreased gonial angles.

The Class III dinaric group had twice the frequency of an increased, mandibular protrusive gonial angle as the Class III dolichocephalic group, yet of the two groups, only the dinaric group contained individuals with decreased gonial angles. The dinaric group also had higher percentages of mandibular protrusive and mandibular retrusive effects than the mesocephalic and brachycephalic.

Mesocephalic Class III and Class I B types showed opposite frequencies of neutral and protrusive effects.

Afro-American Group

The Class III Afro-American groups had the lowest frequencies for increased gonial angles of all Class III

groups and, besides the dinaric Class III group, were the only groups to contain individuals with decreased gonial angles. The Class I mesocephalic group had a similar frequency distribution to the Class III mesocephalic group. The Class I dolichocephalic group contained the least percentage of mandibular protrusive effects and the highest percentage of neutral effects for all groups (Caucasian, Afro-American, Class I, Class III).

TABLE 19

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR GONIAL ANGLE

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	129.2	6.9	122.0	145.0
III Dolicho A	8	122.6	10.6	98.0	132.0
III Meso C	10	129.9	4.5	124.0	137.0
III Meso A	7	127.0	5.5	120.0	135.0
III Brachy C	18	131.9	8.6	118.0	153.0
III Dinaric C	7	132.8	2.5	130.0	137.0
I Dolicho C	16	124.3	6.9	112.0	136.0
I Dolicho A *	14	124.2	5.3	117.0	138.0
I Meso C	38	127.0	5.5	118.0	137.0
I Meso A *	15	125.6	7.1	116.0	138.0
I Brachy C	24	129.0	8.0	118.0	150.0
I Dinaric C	19	123.5	6.7	111.0	135.0

TABLE 20

DISTRIBUTION PERCENTAGES FOR GONIAL ANGLE ALIGNMENT

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	36	64	....
III Dolicho A	25	63	12
III Meso C	60	40	....
III Meso A	29	43	28
III Brachy C	56	44	....
III Dinaric C	71	....	29
I Dolicho C	25	50	25
I Dolicho A	7	79	14
I Meso C	29	68	3
I Meso A	27	53	20
I Brachy C	38	50	12
I Dinaric C	16	58	26

9.Maxillary nerve/palatal plane alignment

(see Tables 21 and 22)

The majority of the Class III groups showed a greater tendency toward a counterclockwise alignment of the palate (mandibular protrusive effect). The brachycephalic and dinaric Class III groups started to approach equal percentages for a counterclockwise and a clockwise rotation of the palate.

Except for the Class I Afro-American dolichocephalic group, all other Class I groups had almost equal clockwise and counterclockwise frequencies.

TABLE 21

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR MAXILLARY NERVE/PALATAL PLANE ALIGNMENT

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	-0.3	0.9	-1.0	1.0
III Dolicho A	8	-0.6	0.7	-1.0	1.0
III Meso C	10	-0.4	1.0	-1.0	1.0
III Meso A	7	-0.7	0.8	-1.0	1.0
III Brachy C	18	-0.1	1.0	-1.0	1.0
III Dinaric C	7	0.0	1.0	-1.0	1.0
I Dolicho C	16	-0.1	0.9	-1.0	1.0
I Dolicho A *	14	-0.8	0.6	-1.0	1.0
I Meso C	38	-0.2	0.9	-1.0	1.0
I Meso A *	15	-0.1	0.9	-1.0	1.0
I Brachy C	24	-0.1	0.9	-1.0	1.0
I Dinaric C	19	0.2	1.0	-1.0	1.0

TABLE 22

DISTRIBUTION PERCENTAGES FOR MAXILLARY NERVE/PALATAL PLANE ALIGNMENT

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	55	18	27
III Dolicho A	75	12	12
III Meso C	70	....	30
III Meso A	86	....	14
III Brachy C	50	11	39
III Dinaric	43	14	43
I Dolicho C	44	19	38
I Dolicho A	86	7	7
I Meso C	50	16	34
I Meso A	40	27	33
I Brachy C	46	16	38
I Dinaric C	37	10	53

10.Curve of Spee

(see Tables 23 and 24)

Approximately one-third (39%) of the Class III group manifested a curve of Spee less than 1.5mm. It was noted that of the Class III subjects with a curve of Spee greater than 1.5mm, roughly half showed a more or less typical occlusal "curve". The remainder had a flat occlusal plane posteriorly but with a vertical drift only of the lower anterior teeth. Thus, while the incisors are elevated into the open cross-bite area, there does not exist an occlusal "curve". This difference constitutes a configurational variation of the occlusal plane in the Class III's.

TABLE 23

MEANS, STANDARD DEVIATIONS, MAXIMUM AND MINIMUM VALUES FOR CURVE OF SPEE

Group	N	Mean	Standard Deviation	Minimum Value	Maximum Value
III Dolicho C	11	2.9	2.4	-0.5	8.0
III Dolicho A	8	1.9	1.9	-0.5	4.4
III Meso C	10	1.9	1.7	-0.5	4.4
III Meso A	7	2.1	2.6	-0.5	6.0
III Brachy C	18	2.1	2.1	-3.0	6.0
III Dinaric C	7	1.9	0.7	0.8	2.8
I Dolicho C	16	1.8	1.7	-1.0	5.2
I Dolicho A *	14	1.4	1.8	-1.0	4.0
I Meso C	38	2.1	1.8	-2.0	6.0
I Meso A *	15	1.5	1.6	-2.0	4.0
I Brachy C	24	1.5	1.5	-0.5	5.0
I Dinaric C	19	2.3	1.6	0.0	5.4

TABLE 24

DISTRIBUTION PERCENTAGES FOR CURVE OF SPEE

Group	Mandibular Protrusive Effect	Neutral Effect	Mandibular Retrusive Effect
III Dolicho C	....	18	82
III Dolicho A	....	38	63
III Meso C	....	40	60
III Meso A	....	43	57
III Brachy C	6	17	78
III Dinaric C	....	14	86
I Dolicho C	....	44	56
I Dolicho A	....	64	36
I Meso C	3	34	63
I Meso A	7	33	60
I Brachy C	....	42	58
I Dinaric C	....	26	74

Inferential Statistics

T-Tests were used to determine whether gender differences were present in each headform group. The results are listed in Tables 25-36.

In the Class I dolichocephalic Caucasian group, significant differences between males and females were seen for variable curve of Spee (see Table 25). The curve of Spee in the females was greater than in the males. In the Class I mesocephalic Caucasian group, significant differences were also seen between male and female for the variable curve of Spee (see Table 27). In this group the curve of Spee was greater in the males than in the females.

The Class III dolichocephalic Caucasian group showed significant gender differences for the variable middle cranial fossa and posterior maxillary relative alignment (see Table 31). Females showed an anteriorly aligned MCF (mandibular retrusive), while the males had a more upright, posterior MCF alignment. It should be noted that this group contained only two females.

The Class III mesocephalic Afro-American group demonstrated significant gender differences for the variables middle cranial fossa and ramus alignment (see Table 34). Females showed more of a mandibular retrusive tendency than males for these two variables.

In the Class III dinaric Caucasian group females were seen to have significantly larger gonial angles than males (see Table 36).

TABLE 25

T-TEST - CLASS I DOLICHOCEPHALIC CAUCASIAN MALE VS. FEMALE

	Male (N=9)		Female (N=7)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-7.3	2.7	-7.8	2.6	NS
Agg-SPr,IPr	-3.6	1.6	-3.6	1.4	NS
MCF	-0.1	3.9	-0.5	1.7	NS
Ramus	2.9	2.9	1.0	2.2	NS
R/MCF	-0.7	3.8	0.1	4.8	NS
Arch-A,B	-7.5	4.0	-7.6	4.5	NS
Arch-SPr,IPr	-2.8	3.3	-3.4	3.7	NS
PM Vertical	2.7	4.1	1.5	1.9	NS
Gonial angle	124.0	8.2	124.6	5.4	NS
Curve of Spee	1.1	1.8	2.8	1.1	$P < 0.05$

TABLE 26

T-TEST - CLASS I DOLICHOCEPHALIC AFRO-AMERICAN MALE VS. FEMALE

	Male (N=6)		Female (N=8)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-0.5	6.1	-1.8	2.7	NS
Agg-SPr,IPr	1.0	3.5	0.8	2.3	NS
MCF	3.3	1.8	2.8	1.9	NS
Ramus	5.7	3.2	5.3	1.7	NS
R/MCF	-4.8	2.7	-4.7	1.9	NS
Arch-A,B	0.9	6.7	0.1	2.8	NS
Arch-SPr,IPr	2.5	4.1	2.7	3.3	NS
PM Vertical	2.4	4.0	2.5	2.7	NS
Gonial angle	124.2	3.5	124.3	6.6	NS
Curve of Spee	1.3	1.9	1.4	1.9	NS

Table 27

T-TEST - CLASS I MESOCEPHALIC CAUCASIAN MALE VS. FEMALE

	Male (N=16)		Female (N=22)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-8.0	2.8	-7.5	2.3	NS
Agg-SPr,IPr	-4.0	2.0	-3.9	1.6	NS
MCF	-0.2	3.6	1.2	1.8	NS
Ramus	0.1	2.5	0.2	2.1	NS
R/MCF	1.0	2.8	0.6	3.0	NS
Arch-A,B	-9.1	5.0	-9.9	3.2	NS
Arch-SPr,IPr	-5.3	4.2	-6.3	2.7	NS
PM Vertical	0.8	4.1	-1.1	2.4	NS
Gonial angle	126.3	5.8	127.5	5.4	NS
Curve of Spee	2.8	1.7	1.5	1.6	$P < 0.05$

TABLE 28

T-TEST - CLASS I MESOCEPHALIC AFRO-AMERICAN MALE VS. FEMALE

	Male (N=6)		Female (N=9)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-3.4	3.9	-4.5	5.1	NS
Agg,SPr,IPr	-0.3	2.9	-1.5	3.5	NS
MCF	2.3	1.8	2.3	3.1	NS
Ramus	5.9	2.5	4.0	3.4	NS
R/MCF	-2.7	4.6	-4.0	3.8	NS
Arch-A,B	-3.8	6.7	-2.9	6.2	NS
Arch-SPr,IPr	-0.5	5.6	0.1	5.3	NS
PM Vertical	3.7	2.4	1.6	4.5	NS
Gonial angle	127.3	5.2	124.4	8.2	NS
Curve of Spee	1.4	1.6	1.5	1.7	NS

TABLE 29

T-TEST - CLASS I BRACHYCEPHALIC CAUCASIAN MALE VS. FEMALE

	Male (N=12)		Female (N=12)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-7.8	3.1	-7.0	1.9	NS
Agg-SPr,IPr	-4.6	2.6	-4.0	1.0	NS
MCF	0.2	2.1	-0.8	2.4	NS
Ramus	0.1	1.6	0.1	2.0	NS
R/MCF	2.8	3.4	1.9	3.5	NS
Arch-A,B	-11.6	5.0	-8.5	3.5	NS
Arch-SPr,IPr	-8.6	3.8	-5.6	3.2	NS
PM Vertical	-0.2	3.2	0.9	2.2	NS
Gonial angle	131.2	8.8	126.9	6.8	NS
Curve of Spee	1.0	1.1	2.0	1.7	NS

TABLE 30

T-TEST - CLASS I DINARIC CAUCASIAN MALE VS. FEMALE

	Male (N=16)		Female (N=3)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-4.4	3.5	-5.3	4.5	NS
Ag-SPr,IPr	-1.6	2.3	-2.4	4.8	NS
MCF	-1.1	2.9	-1.5	1.3	NS
Ramus	1.9	2.5	0.0	0.9	NS
R/MCF	2.5	3.3	-1.3	2.9	NS
Arch-A,B	-5.9	5.5	-6.2	3.7	NS
Arch-SPr,IPr	-3.1	4.4	-3.0	4.2	NS
PM Vertical	3.1	4.0	1.5	1.7	NS
Gonial angle	122.4	6.6	129.6	2.3	NS
Curve of Spee	2.4	1.6	1.8	1.6	NS

TABLE 31

T-TEST - CLASS III DOLICHOCEPHALIC CAUCASIAN MALE VS. FEMALE

	Male (N=9)		Female (N=2)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-11.8	3.5	-12.0	3.5	NS
Agg-SPr,IPr	-8.6	3.1	-7.5	0.4	NS
MCF	-1.3	2.4	2.8	0.1	$P < 0.01$
Ramus	-0.7	3.1	1.8	3.3	NS
R/MCF	2.3	3.6	-3.7	1.3	NS
Arch-A,B	-13.1	4.6	-11.3	4.5	NS
Arch-SPr,IPr	-9.4	3.6	-6.9	1.9	NS
PM Vertical	0.8	3.2	-1.0	4.7	NS
Gonial angle	127.4	5.0	137.0	11.3	NS
Curve of Spee	2.8	2.6	3.8	1.8	NS

TABLE 32

T-TEST - CLASS III DOLICHOCEPHALIC AFRO-AMERICAN MALE VS. FEMALE

	Male (N=4)		Female (N=4)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-11.4	2.9	-9.4	1.8	NS
Agg-SPr,IPr	-6.9	1.3	-7.4	2.7	NS
MCF	1.8	2.3	3.9	3.1	NS
Ramus	2.7	1.7	4.4	4.3	NS
R/MCF	-3.0	4.7	-6.5	7.5	NS
Arch-A,B	-10.4	4.6	-7.3	5.5	NS
Arch-SPr,IPr	-6.0	6.1	-5.4	5.4	NS
PM Vertical	0.9	3.9	0.5	2.9	NS
Gonial angle	127.7	4.4	117.5	13.2	NS
Curve of Spee	2.2	2.3	1.6	1.6	NS

TABLE 33

T-TEST - CLASS III MESOCEPHALIC CAUCASIAN MALE VS. FEMALE

	Male (N=4)		Female (N=6)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-9.2	1.4	-10.3	4.4	NS
Agg-SPr,IPr	-6.7	1.6	-6.4	2.8	NS
MCF	-0.8	1.1	0.0	1.2	NS
Ramus	0.3	1.9	-0.5	1.9	NS
R/MCF	2.0	1.9	2.4	1.9	NS
Arch-A,B	-10.9	2.2	-12.8	4.9	NS
Arch-SPr,IPr	-8.3	2.1	-8.6	3.5	NS
PM Vertical	1.0	2.6	-0.5	1.8	NS
Gonial angle	128.0	3.6	131.2	4.8	NS
Curve of Spee	1.4	1.2	2.3	1.9	NS

TABLE 34

T-TEST - CLASS III MESOCEPHALIC AFRO-AMERICAN MALE VS. FEMALE

	Male (N=3)		Female (N=4)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-15.7	3.7	-12.8	1.1	NS
Agg-SPr,IPr	-10.0	1.6	-9.5	2.5	NS
MCF	-0.4	2.2	3.4	1.1	$P < 0.05$
Ramus	1.3	0.2	5.7	2.4	$P < 0.05$
R/MCF	-2.6	5.3	-3.1	1.8	NS
Arch-A,B	-13.0	5.6	-13.2	1.4	NS
Arch-SPr,IPr	-7.2	4.5	-10.8	3.1	NS
PM Vertical	1.6	2.3	2.2	2.7	NS
Gonial angle	126.3	7.8	127.5	4.4	NS
Curve of Spee	3.2	3.3	1.3	2.0	NS

TABLE 35

T-TEST - CLASS III BRACHYCEPHALIC
CAUCASIAN MALE VS. FEMALE

	Male (N=7)		Female (N=11)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-11.9	2.7	-10.9	4.0	NS
Agg-SPr,IPr	-7.7	1.6	-7.9	2.6	NS
MCF	0.5	2.3	-0.5	1.8	NS
Ramus	-0.8	2.3	-1.2	2.1	NS
R/MCF	3.1	2.9	1.8	2.3	NS
Arch-A,B	-16.0	4.3	-12.7	4.7	NS
Arch-SPr,IPr	-11.7	3.8	-9.7	3.8	NS
PM Vertical	-1.3	3.6	-0.7	2.7	NS
Gonial angle	129.9	7.2	133.3	9.4	NS
Curve of Spee	2.7	0.8	1.7	2.6	NS

TABLE 36

T-TEST - CLASS III DINARIC CAUCASIAN MALE VS. FEMALE

	Male (N=3)		Female (N=4)		
Variable	$\bar{x}$	SD	$\bar{x}$	SD	Statistical Significance
Agg-A,B	-13.8	8.4	-12.9	1.8	NS
Agg-SPr,IPr	-7.6	5.4	-7.6	1.1	NS
MCF	0.2	3.5	-1.9	1.5	NS
Ramus	0.0	4.4	-2.5	1.4	NS
R/MCF	1.7	1.6	3.8	2.0	NS
Arch-A,B	-16.3	7.2	-15.0	1.7	NS
Arch-SPr,IPr	-10.3	4.4	-9.6	1.6	NS
PM Vertical	-0.2	3.1	-0.6	1.2	NS
Gonial angle	130.7	1.2	134.5	1.9	$P < 0.05$
Curve of Spee	2.1	0.7	1.8	0.8	NS

Mann-Whitney and Kruskal-Wallis Tests were used to compare headform groups. The results of these comparisons are listed in Tables 37-47.

Significant differences were seen in the dolichocephalic Caucasian Class III and Class I comparison (see Table 37). When only females from both groups were compared, the females in the Class III group demonstrated a significantly greater tendency toward a more anteriorly inclined MCF (mandibular retrusive effect). The females in the Class I group had, on average, a neutral MCF alignment. Arch lengths also differed between the two groups. In the Class III groups the relative mandibular arch length was much longer than in the Class I group.

The mesocephalic Caucasian Class III and Class I comparison showed significant differences in arch lengths when measured at SPr and IPr points (see Table 38). Relative mandibular arch lengths in the Class III were longer than in the Class I.

Differences in relative mandibular arch length were seen between the brachycephalic Caucasian Class III and Class I groups (see Table 39). In all groups, the relative mandibular arch length was longer in the Class III group.

Dinaric Caucasian Class III and Class I comparisons revealed significant differences in many variables (see Table 40). There was a tendency toward a mandibular

retrusive ramus alignment in the Class I and a tendency toward a mandibular protrusive ramus alignment in the Class III. PM vertical length was longer in the Class I than in the Class III. A relatively longer mandibular arch length was seen in the Class III than in the Class I. The gonial angle in the Class III group was significantly larger than in the Class I group (also for male/male comparison).

Differences between the dolichocephalic Afro-American Class III and Class I were demonstrated for arch lengths (see Table 41). All Class III groups had a relatively long mandibular arch, on average, and the Class I groups had a relatively neutral or long maxillary arch, on average.

Mesocephalic Afro-American Class III and Class I comparisons revealed significant differences for many of the variables (see Table 42). In the male/male comparison, significant differences in ramus alignment were seen. The Class I male had a much greater tendency for a ramus with a mandibular retrusive alignment than did the Class III. Relative mandibular arch lengths were longer in the Class III than in the Class I.

In the Class I Afro-American dolichocephalic and mesocephalic comparison, significant differences were seen for the maxillary nerve/palatal plane alignment (see Table 43). The dolichocephalic had a greater tendency for

a counterclockwise rotation than did the mesocephalic.

Comparing the dolichocephalic Afro-American and Caucasian Class III groups, significant differences are seen for middle cranial fossa alignment, ramus alignment and ramus width relative to the middle cranial fossa (see Table 44). In the Afro-American group, the middle cranial fossa tended to be more anteriorly aligned (mandibular retrusive effect) than the Caucasian group. This finding was also seen in the male/male comparison. Ramus alignment in the Afro-American group also tended to have a mandibular retrusive effect while the Caucasian group had a more neutral ramus alignment on average. The ramus width in the Afro-American group tended to be much wider than in the Caucasian group. Ramus width in the Caucasian group produced a mandibular retrusive effect while ramus width in the Afro-American group produced a mandibular protrusive effect.

In the Class III mesocephalic Afro-American and Caucasian comparison, some of the variables showed the same significant differences as in the dolichocephalic Class III comparison (see Table 45). Female/female comparisons for the variable middle cranial fossa alignment showed the Afro-American female to have a greater tendency for an anteriorly aligned middle cranial fossa. In contrast, the average middle cranial fossa alignment was neutral in the Caucasian female. As in the

dolichocephalic groups, the Afro-American group showed a greater tendency for mandibular retrusive effects in ramus alignment and mandibular protrusive effects in ramus width relative to the middle cranial fossa. The Caucasians had a more neutral to mandibular protrusive ramus alignment and mandibular retrusive effects ramus width. Female/female comparisons showed the same findings for ramus alignment.

No significant differences were seen for any of the variables between Class III Caucasian dolichocephalics, mesocephalics, brachycephalics or dinarics (see Table 47).

TABLE 37

MANN-WHITNEY TEST - DOLICHOCEPHALIC CAUCASIAN CLASS III VS. CLASS I

Variable	Combined (N_1=11,N_2=16)	Male/Male (N_1=9,N_2=9)	Female/Female (N_1=2,N_2=7)
MCF	NS	NS	P < 0.05
Ramus	NS	...	...
Ramus/MCF	NS	...	...
Arches-A,B	P < 0.01	...	...
Arches-SPr,IPr	P < 0.01	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	NS	NS

TABLE 38

MANN-WHITNEY TEST - MESOCEPHALIC CAUCASIAN CLASS III VS. CLASS I

Variable	Combined (N_1=10,N_2=38)	Male/Male (N_1=4,N_2=16)	Female/Female (N_1=6,N_2=22)
MCF	NS	...	...
Ramus	NS	...	...
Ramus/MCF	NS	...	...
Arches-A,B	NS	...	...
Arches-SPr,IPr	P < 0.05	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	NS	NS

TABLE 39

MANN-WHITNEY TEST - BRACHYCEPHALIC CAUCASIAN CLASS III VS. CLASS I

Variable	Combined (N_1=18,N_2=24)	Male/Male (N_1=7,N_2=12)	Female/Female (N_1=11,N_2=12)
MCF	NS	...	...
Ramus	NS	...	...
Ramus/MCF	NS	...	...
Arches-A,B	$P < 0.01$	...	...
Arches-SPr,IPr	$P < 0.01$	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 40

MANN-WHITNEY TEST - DINARIC CAUCASIAN CLASS III VS. CLASS I

Variable	Combined (N_1=7,N_2=19)	Male/Male (N_1=3,N_2=16)	Female/Female (N_1=4,N_2=3)
MCF	NS	...	...
Ramus	$P < 0.05$	...	...
Ramus/MCF	NS	...	...
Arches-A,B	$P < 0.01$	...	...
Arches-SPr,IPr	$P < 0.01$	...	...
PM Vertical	$P < 0.05$	...	...
Gonial angle	$P < 0.01$	$P < 0.05$	NS
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 41

MANN-WHITNEY TEST - DOLICHOCEPHALIC AFRO-AMERICAN CLASS III VS. CLASS I (BIMAXILLARY PROTRUSIVE)

Variable	Combined (N_1=8,N_2=14)	Male/Male (N_1=4,N_2=6)	Female/Female (N_1=4,N_2=8)
MCF	NS	...	...
Ramus	NS	...	...
Ramus/MCF	NS	...	...
Arches-A,B	$P < 0.01$	...	...
Arches-SPr,IPr	$P < 0.01$	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 42

MANN-WHITNEY TEST - MESOCEPHALIC AFRO-AMERICAN CLASS III VS. CLASS I (BIMAXILLARY PROTRUSIVE)

Variable	Combined (N_1=7,N_2=15)	Male/Male (N_1=3,N_2=6)	Female/Female (N_1=4,N_2=9)
MCF	NS	NS	NS
Ramus	NS	$P < 0.05$	NS
Ramus/MCF	NS	...	...
Arches-A,B	$P < 0.01$	...	...
Arches-SPr,IPr	$P < 0.01$	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 43

MANN-WHITNEY TEST - CLASS I AFRO-AMERICAN (BIMAXILLARY PROTRUSIVE DOLICHOCEPHALIC VS. MESOCEPHALIC

Variable	Combined (N_1=14,N_2=15)	Male/Male (N_1=6,N_2=6)	Female/Female (N_1=8,N_2=9)
MCF	NS	...	...
Ramus	NS	...	...
Ramus/MCF	NS	...	...
Arches-A,B	NS	...	...
Arches-SPr,IPr	NS	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	$P < 0.05$	...	...
Curve of Spee	NS	...	...

TABLE 44

MANN-WHITNEY TEST - CLASS III DOLICHOCEPHALIC AFRO-AMERICAN VS. CAUCASIAN

Variable	Combined (N_1=8,N_2=11)	Male/Male (N_1=4,N_2=9)	Female/Female (N_1=4,N_2=2)
MCF	$P < 0.05$	$P < 0.05$	NS
Ramus	$P < 0.05$	...	...
Ramus/MCF	$P < 0.05$	...	...
Arches-A,B	NS	...	...
Arches-SPr,IPr	NS	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 45

MANN-WHITNEY TEST - CLASS III MESOCEPHALIC
AFRO-AMERICAN VS. CAUCASIAN

Variable	Combined (N_1=7,N_2=10)	Male/Male (N_1=3,N_2=4)	Female/Female (N_1=4,N_2=6)
MCF	NS	NS	$P < 0.05$
Ramus	$P < 0.01$	NS	$P < 0.05$
Ramus/MCF	$P < 0.01$	...	...
Arches-B,B	NS	...	...
Arches-SPr,IPr	NS	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 46

MANN-WHITNEY TEST - CLASS III AFRO-AMERICAN
DOLICHOCEPHALIC VS. MESOCEPHALIC

Variable	Combined (N_1=8,N_2=7)	Male/Male (N_1=4,N_2=3)	Female/Female (N_1=4,N_2=4)
MCF	NS	NS	NS
Ramus	NS	NS	NS
Ramus/MCF	NS	...	...
Arches-A,B	NS	...	...
Arches-SPr,IPr	NS	...	...
PM Vertical	NS	...	...
Gonial angle	NS	...	...
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

TABLE 47

KRUSKAL-WALLIS TEST - CLASS III CAUCASIAN
DOLICHOCEPHALIC VS. MESOCEPHALIC VS.
BRACHYCEPHALIC VS. DINARIC

Variable	Combined (N_1=11,N_2=10, N_3=18,N_4=7)	Male/Male (N_1=9,N_2=4, N_3=7,N_4=3)	Female/Female (N_1=2,N_2=6, N_3=11,N_4=4)
MCF	NS	NS	NS
Ramus	NS	...	...
Ramus/MCF	NS	...	...
Arches-A,B	NS	...	...
Arches-SPr,IPr	NS	...	...
PM Vertical	NS	...	...
Gonial angle	NS	NS	NS
Nerve/palate	NS	...	...
Curve of Spee	NS	...	...

DISCUSSION

The different basic headform types are each typically characterized, in general, by a particular configuration of craniofacial features. A dolichocephalic headform is long and narrow and the face usually has leptoproscopic features - a long, narrow face with a relatively large, elongate nose. The various regional anatomic relationships, as outlined in previous studies, tend to have mandibular retrusive effects. A tendency for a Class II dental relationship exists as a composite result of these retrusive effects. The brachycephalic, at the other extreme, has a short and wide headform and euryproscopic facial features - a relatively wide, flatter, and shorter face but with a population tendency toward a more orthognathic or prognathic profile. Many of the underlying, regional anatomic relationships have mandibular protrusive effects. A greater tendency for a Class III dental relationship thus exists.

However, there also exist Class III individuals who are long and narrow faced dolichocephalics, thereby comprising an entirely separate morphologic subgroup within this headform category. The present investigation is intended to determine and describe the composite of features that underlie the anatomic basis for this distinctive, variant group and to note how it is similar

to or different from Class III brachycephalics and dinarics as well as Class I dolichocephalics and mesocephalics.

Regional anatomic relationships in the mesocephalic headform have been shown to be truly intermediate between the dolichocephalic and brachycephalic types (Bhat and Enlow 1985). Dinarics, which are "brachycephalized dolichocephalics", are also intermediate but in a different sense. They are characterized by some strong leptoproscopic facial features but with a hyperbrachycephalic headform and a greater tendency for mandibular protrusion than in dolichocephalics.

Bhat and Enlow (1985) have shown that the frequency of anterior versus posterior inclination of the middle cranial fossa differs according to headform group. Ramus alignment, posterior maxillary vertical height, and arch length characteristics were also found to differ. Frequencies of A and B types (A point protrusive versus B point protrusive) were also found to differ.

For Class I individuals, depending on the individual's combination of these craniofacial anatomic variables, an intrinsic Class III (versus Class II) tendency exists if the regional mandibular protrusive effects predominate over any mandibular retrusive effects that may also exist. This identifies the "B" type of Class I individuals. For the "A" type, mandibular retrusive

regional features predominate. Thus, the B type of Class I is in the Class III direction, and the A type in the Class II direction. In all cases, the process of growth can produce some degree of adjustment for these tendencies by regional developmental "balancing of imbalances", thereby lessening the built-in protrusive/retrusive features (Enlow 1990).

Marked differences were found between the Class III and Class I B group (present study) and Class I A and Class II groups (Bhat and Enlow 1985) for frequency distributions of the various regional anatomic variables according to headform. Not suprisingly, no statistically significant differences were seen between the Class III Caucasian groups for all headform types in the magnitude of the regional morphologic effects. If a given mandibular effect occurs, it is just as "much" in any headform group, but, the frequencies of such effects occuring in the headform groups are often very different. That is, some (not necessarily all) of the same basic, underlying anatomy that leads to a Class III brachycephalic likewise exists within a dolichocephalic who is also a Class III. This constitutes a morphologic variation of the dolichocephalic that distinguishes it from the structural features often asociated with the long-narrow type of headform. This is deemed important, since two contrasting categories of the Class I (the A and B types) exist. Corresponding differ-

ences in growth and development and, likely, responses to different clinical procedures thus may also exist. This now needs to be studied and catalogued.

Characteristic headform types historically have predominated in particular areas of the world. For example, Far Eastern populations have a brachycephalic predominance whereas a mix of dolichocephalic and mesocephalic as well as brachycephalic individuals are found in the various parts of the Western world. This is one explanation for the greater incidence of Class II tendencies in the United States and many parts of Europe contrasted with a greater frequency of Class III and bimaxillary protrusive tendencies in the Far East.

Just as anatomic heterogeneity exists within each of the Class I, II and III groups, the present study also demonstrates that such heterogeneity is also existent within each of the various headform groups. Discrete categories have traditionally been used to describe such things as malocclusion (e.g. Class I, II, III) and headform types (e.g. dolichocephalic, brachycephalic). Malocclusion and headform are actually entities with a continuous range of existence. Variables in separate categories but very close in range are likely to have similar or overlappping features. For example, the fact that the Class III dinaric group behaved very similarly to the Class III brachycephalic group in this study may

be due to a close range between the brachycephalic and hyperbrachycephalic headform groups. Thus, some of the heterogeneity in headform and malocclusion types may be a result of the continuous nature of anatomic variables.

Dolichocephalics have been typically classified as a more or less homogeneous headform group. It is likely that dolichocephalics and other headform types from different geographic regions will have different combinations of anatomical features. This heterogeneity in headform may have resulted in a number of ways. Long-established populations in separate geographic regions likely have had different "genetic" patterns which evolved along different orthogenous lines. In each headform type, then, subgroups relating to these population characteristics may exist. Further study is needed to identify and describe subgroups. Headform population characteristics have been deccribed in the anthropological literature but finer detail is needed to be organized for the purpose of cataloguing headform as it relates to craniofacial morphology and malocclusion.

Differences in headform and facial pattern may also emerge within larger, previously more homogeneous populations because, since the beginning, population migrations and wars have introduced admixtures of many different genetic patterns into gene pools, and ethnic customs into epigenetic patterns. Thus, even though

dolichocephalics have been characterized as having mostly leptoproscopic and often mandibular retrusive anatomical relationships in craniofacial form, if some mandibular protrusive features (such as middle cranial fossa alignment) have been introduced, or if the magnitude of any given mandibular protrusive effect is great enough, a Class III or mandibular and bimaxillary protrusive composite can result. Whether or not dolichocephalic Class III variant subgroups are associated with any particular ethnic identities or geographic origins is not presently known but needs to be studied.

In this study, the dolichocephalic Class III sample was extremely variable. No two dolichocephalic Afro-Americans or Caucasians had all of the same composite combinations of features. However, one commonly shared characteristic is that all have a longer mandibular arch length relative to the maxillary arch.

In general, differences between means of the variables for males and females were not significant. Group comparisons of headform types for actual measurements (in contrast to frequency distributions) did not show major differences. Distribution percentages of mandibular protrusive and mandibular retrusive effects in each headform group, however, were revealing.

Comparison of the Caucasian Class III Dolichocephalic with the Caucasian Class I A Type

The Class III dolichocephalic described in the present study is compared with the Class I A as previously described by Enlow and coworkers (1971a) and the dolichocephalic Class I and II groups previously described by Bhat and Enlow (1985). Similar frequency distributions for all of the various regional anatomic relationships occurred for the latter groups, which are distinctively different than the dolichocephalic Class III.

In the dolichocephalic Class III, population tendencies toward mandibular protrusive effects exist for the middle cranial fossa alignment (55%), the alignment of the ramus (45%), and mandibular arch length relative to the maxillary arch (100%;see Tables 4,8,10). These same anatomic relationships in the Class I A and Class II groups (Bhat and Enlow study 1985), conversely, have mandibular retrusive tendencies (57%, 77% and 69% respectively).

Although the above distinct differences exist, these contrasting groups did share one common feature, a vertically long nasomaxillary region (mandibular retrusive effect), thus retaining the tendency for a characteristically elongate midface in the dolichocephalic, even when a Class III malocclusion exists (about three-fourths "long" or "neutral", with the remainder "short"; see Table 18).

As in most headform groups and occlusal types, the Class III dolichocephalic has a ramus which often serves a "compensatory" function. That is, the severity of mandibular protrusion is lessened by a developmental (epigenetic) narrowing of the ramus by its functional soft tissues and osteogenic connective tissues to match the more upright alignment and anteroposterior foreshortening of the middle cranial fossa and underlying pharynx (Enlow et al.1971B). Class III and Class I B groups had a greater frequency distribution for a narrow ramus width (50-55%, see Table 12) compared to the Class I and Class II groups (33%) of Bhat and Enlow's study in 1985.

In summary, the composite predominance of regional mandibular protrusive relationships in this variant of the dolichocephalic headform is the developmental and anatomic basis for a corresponding expression of the Class III type of malocclusion. Conversely, in other dolichocephalic leptoproscopics, a predominance of mandibular retrusive regional anatomic conditions in the Class I A and Class II groups exists. These two contrasting occlusal variations, within the same headform type (dolichocephalic) based on composite regional craniofacial morphology, thereby defines two distinct sub-groupings, each with different, specific anatomic combinations.

Comparison of Caucasian Dolichocephalic Class III with Caucasian Dolichocephalic Class I B

A key feature shared by these two groups is a mandibular arch length that is long relative to maxillary arch length (100%;see Table 4). However, a significant difference exists in the magnitude of this mandibular protrusive relationship, which is greater in the Class III.

In general, frequency distributions for the regional anatomic variables show a similar spread. This underscores the common anatomic relationships shared by a Class III and a Class I B of any headform group. In the Class III, however, a shift is seen for certain variables toward a higher incidence of regional mandibular protrusive relationships combined with a lesser frequency of neutral relationships. This occurs for the middle cranial fossa alignment, ramus alignment, and the vertical length of the maxilla (see Tables 8, 10 and 18).

In the Class III dolichocephalic, also, a higher frequency of a "compensatory" ramus exists (see Table 12). While this softens the malocclusion severity in the Class III, it does not, appropriately, exist in most individuals having the Class I B condition.

The sum of the above-described comparative features helps to understand the morphologic reasons why the Class I B is in the Class III direction, in contrast to the

Class I A which is in the Class II direction. It also serves to clarify the anatomic reasons why a narrow and long-faced, long-nosed dolichocephalic can exhibit a mandibular protrusive, Class III craniofacial composite rather than the more routinely encountered mandibular retrusive configuration seen in many dolichocephalic leptoproscopics. As explained later, how these regional tendencies for mandibular protrusion or retrusion respond to various treatment modalities is not presently catalogued in any meaningful detail. Nonetheless, distinctive morphologic subgroupings are evident and need to be recognized as such.

Comparison of the Caucasian Class III Dolichocephalic with the Caucasian Class III Brachycephalic

These groups share similar mandibular protrusive trends for the middle cranial fossa (MCF) alignment and for ramus alignment (see Tables 8 and 10). Interestingly, the MCF distribution frequency in dolichocephalics (55%) is even greater than among the brachycephalics (44%). This is a significant feature, as well, that distinguishes the dolichocephalic Class III from other dolichocephalic groups.

Mandibular arch lengths that are consistently long relative to the maxilla characterize both Class III headform groups (see Tables 4 and 6). This is a principal

factor for the Class III in any headform type.

For the vertical length of the midface (PM; see Table 18), a noteworthy difference exists between the dolichocephalic and brachycephalic Class III's. The brachycephalic has fewer "long" (17%) and more "neutral" (50%), whereas the dolichocephalic has more "long" (55%). This skews the population tendencies toward a longer dolichocephalic midface and a shorter brachycephalic midface, even though both share a Class III malocclusion. It is noted that these midfacial features relate to the Caucasian, since an Oriental subgroup exists that can differ (Enlow 1990).

A similar decrease in mandibular retrusive relationships and an increase in neutral effects is seen in the brachycephalic Class III for ramus alignment (see Table 10) and MCF alignment (see Table 8), thus pointing to another contrasting morphologic feature that distinguishes these two Class III headform types. This further underscores the existence and significance of subgrouping when considering underlying morphologic variations as it relates to malocclusion taxonomy.

Added to the above contrasting features between these two headform Class III types is the alignment relationship of the mandibular corpus to the ramus (e.g., the "gonial angle"; see Table 20). The brachycephalic has a higher frequency (56% compared to 36%) of an increased

gonial angle (mandibular protrusive effect, since this elongates the whole mandible), and a lower incidence of a neutral angle (44% compared to 64%). The result augments the tendency toward a Class III.

In general, the brachycephalic thus has frequency distributions for most of the regional anatomic relationships that are skewed toward composite mandibular protrusion and away from mandibular retrusive relationships. The dolichocephalic Class III also has certain regional mandibular protrusive features but, compared to the brachycephalic, has a greater distribution of regional mandibular retrusive relationships. This reflects the elongate, narrowed character of the headform. Nonetheless, the protrusive features dominate the retrusive, and a resultant Class III thereby develops.

Comparison of Caucasian Mesocephalic and Dinaric Class III with Caucasian Dolichocephalic and Brachycephalic Class III

Previous studies showed that Class I and II mesocephalics are indeed intermediate between dolichocephalics and brachycephalics in frequency distributions of the various anatomic variables (Bhat and Enlow 1985). In the present study, the Class III (and Class I B) mesocephalic is also seen to be intermediate but in a somewhat different sense. Most freqiencies were either for neutral effects or were

essentially evenly distributed from retrusive through neutral to protrusive in respective regional effects. However, in the Class III, two of the relationships are shifted to become more comparable to the brachycephalic Class III. One is a "compensatory" ramus (mandibular retrusive because of its narrowing; see Table 12), and the other is the more open gonial angle (mandibular protrusive effect; see Table 20).

The dinaric headform, as customarily described, is often hyperbrachycephalic but with a leptoproscopic-appearing facial composite (e.g., a brachycephalized dolichocephalic; Enlow 1990). Previous study of the Class I and Class II individuals (Bhat and Enlow 1985) showed that a vertically long midface (leptoproscopic-like having a mandibular retrusive effect) exists in combination with an upright middle cranial fossa (brachycephalic-like having a mandibular protrusive effect). The net effect is a vertically elongate, narrow, long-nosed face (lepto-proscopic) but with a much lesser tendency for retro-gnathia than among dolichocephalic leptoproscopics.

In the present study dealing with Class III features among the various headform types, the dinaric Class III appears to behave more closely to the brachycephalic Class III but with slight increases in retrusive effects for the gonial angle and ramus alignment (see Tables 20 and 10 respectively). Unlike long-faced Class I and II

dinarics in the present and previous studies, the midface (PM) tends to be vertically more short (mandibular retrusive effect) rather than long (57% short in the Class III compared to 68-76% long in the Class I and Class II). Indeed, the dinaric Class III in this sample has the highest incidence of a short PM than in any other headform type (see Table 18). The midface appears to be a key factor in the comparison of the Class I and Class III dinaric.

As pointed out by Enlow (1990), different morphologic variations of the dinaric type of headform doubtless exist that remain yet undescribed and uncatalogued. Perhaps some dolicocephalic Class III individuals are actually an undescribed type of dinaric which has not been completely brachycephalized. Gradations in the extents of dinarization such as this, are likely to exist and are undescribed to date. Also, a brachycephalic (not just a dolichocephalic) can also become "hyperbrachycephalized", as perhaps by sleeping habits or cradling. The features of malocclusions in groups such as these also remain unknown at present.These considerations call for study and a much more comprehensive taxonomic system based on real anatomy and differing treatment responses.

The Afro-American Class III

The principal features that characterize and

distinguish this group include a strong tendency toward an anteriorly inclined middle cranial fossa, a downward and backward aligned ramus, an elongate mandibular arch relative to the maxilla and a notably broad ramus relative to the middle cranial fossa (see Tables 8, 10, 4 and 12 respectively). These findings are similar to the findings of Enlow and others (1982, 1971a). The Afro-American has a stronger tendency for an anteriorly inclined middle cranial fossa (71-75%) than the Caucasian Class III (10-36%). The ramus alignment is rotated downward and backward (75-100%;mandibular retrusive effect) in contrast to the more neutral (9-60%) or forward alignment (20-57%) seen in the Caucasian Class III groups. There is also a lower frequency of opened gonial angles (25-29%) compared to Caucasians (36-71%). The tendency toward a long naso-maxillary complex (see Table 18) is in contrast to the short nasomaxillary complex seen in the Afro-American Class III of other studies (Enlow et al. 1982). The net effect, however, is a strong tendency for mandibular or bimaxillary protrusion.

Sample Size and Diversity

The size and makeup of the sample groups influence the results of comparisons among groups. In a sample that is relatively small, it can be impossible to detect small differences or consistent variations among the groups.

Further studies on larger samples that include ethnic considerations, geographic factors and sleeping habits may reveal more sensitive differences within Class III groups and between Class III and Class I groups. Also, any given headform group may not be homogeneous. Heterogeneity of groups results in a large spread of data making it more difficult to identify variations within and between groups. Nevertheless, it is evident that distinctive subgroups exist among the Class III, Class I and II, as well as the various conventional headform types. The clinical significance and potential of this is emphaisized, and different geographic-origin and ethnic populations need to be evaluated.

Clinical Implications

Just as subgroups occur for types of facial features and occlusal types, subgroups within each headform type also exist to produce variations on a theme. This makes sense if we think of the extensive range and magnitude of variations that are seen in facial features and occlusal types. The heterogeneous nature of the Class III group is evidenced by the existence of such subgroupings with variations according to different headforms. Also, it appears that the Class III pattern is not the result of a single aberrant developmental growth process or a specific combination of developmental factors. This

implies a multifactorial nature of growth control processes in the basicranium and associated facial structures. Thus it is likely that more information may be gained by further study of the Class III pattern as it occurs in the various subgroups of headform rather than looking at the Class III pattern without taking headform into account. Variations in anatomical relationships are the result of variations in developmental patterns. This is significant in that anatomical groupings having such different developmental characteristics are likely also to respond differently to the various modes of treatment. DiPalma (1983) and Enlow and others (1988) have shown that individuals with different morphological features react differently to a given treatment.

Further study is now needed to characterize, more fully describe, and catalogue the various subgroups, their developmental characteristics and their responses to different treatments. Identification and description of these subgroups will allow one to understand more fully the biological basis for the resultant morphology. Availabilty of this new information would certainly represent a major contribution to the clinical aspects of craniofacial biology, especially once the control processes and timing of craniofacial growth is better understood. Treatments influencing craniofacial growth could be planned and executed more accurately. One could

structure a treatment based on the biological patterns of the individual rather than attempting to make an individual's biological pattern conform to a particular treatment.

SUMMARY AND CONCLUSIONS

The brachcephalic headform is typically characterized by more mandibular protrusive regional anatomic relationships, whereas the dolichocephalic headform is typically characterized by more regional mandibular retrusive anatomic relationships. The focus of this study is to evaluate the nature of the anatomic assembly of regional morphologic components that underlie the Class III malocclusion pattern in the dolichocephalic headform, since this represents a notable variation within the long and narrow headform type.

The objectives were to determine how the regional anatomic relationships in the dolichocephalic Class III group were similar to or different from the typical dolichocephalic, as well as the other Class III headform groups. In addition, all Class III headform groups were compared and, also, Class III headform groups were compared with their corresponding Class I B headform groups. Finally, Afro-American and Caucasian Class III groups were compared.

Individuals in the samples utilized were classified according to conventional headform types and the radiographs then analyzed according to Enlow's counterpart analysis. Means and frequency percentage distributions were determined for 11 regional craniofacial anatomic

variables in each group. Levels of significance using the Mann-Whitney and Kruskal-Wallis Tests were calculated.

The results are summarized by the following conclusions:

1. The Class III dolichocephalic group had tendencies toward mandibular protrusive effects which were opposite to the mandibular retrusive tendencies seen in the Class I A and Class II dolichocephalic groups of previous studies. Thus, a morphologic variation of the dolichocephalic headform exists in which many of the same underlying regional anatomic relationships which lead to a Class III brachycephalic are likewise found in the dolichocephalic Class III. One feature shared by the dolichocephalic groups was a tendency for a vertically long nasomaxillary complex in contrast to most Caucasian Class III brachycephalics.
2. Marked differences are demonstrated between the Class III/I B and Class II/I A groups.
3. No significant differences were seen between the Class III Caucasian groups in the **magnitudes** (not frequency distributions) of the anatomic relationships studied. The various Class III headform groups appear to be generally heterogeneous with many different combinations of regional anatomic effects but which all result in a mandibular protrusive composite. It appears that the Class III pattern is not the result of a single aberrant developmental

growth process or a specific combination of developmental factors. This implies a multifactorial nature of growth control processes in the basicranium and associated facial structures.

4. Class III and Class I B headform groups shared many common anatomic relationships, although mandibular protrusive tendencies and "compensatory" tendencies were usually stronger in the Class III groups. Mandibular arch length relative to the maxillary arch was significantly greater in the Class III groups.
5. In general, the brachycephalic Class III has frequency percentage distributions for most of the regional anatomic relationships that are skewed toward composite mandibular protrusion and away from mandibular retrusive relationships. The dolichocephalic Class III also has certain regional mandibular protrusive features but, compared to the brachycephalic, has a greater distribution of regional mandibular retrusive relationships.
6. Class III mesocephalics generally show more mandibular effects which were either neutral or evenly distributed between protrusive, neutral or retrusive effects compared with the Class III dolichocephalic and brachycephalic.
7. The dinaric Class III group has characteristics very similar to the brachycephalic Class III group. It

differs from the dinaric Class I in that the midface tends to be vertically shorter, thus augmenting mandibular protrusion in the Class III's.

8. The Afro-American Class III group has many mandibular retrusive features with a notably broad ramus which increases the magnitude of the mandibular protrusive character.
9. Subgroups appear to be existent within headform groups. Further study is needed to identify, describe and catalogue these subgroups. Such subgroups are the result of variations in developmental patterns and are likely to respond differently to modes of treatment. This is another area which requires further study. Once the control processes and timing of of craniofacial growth are better understood, this information will be invaluable for understanding and planning treatments which influence craniofacial growth.

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