Facial Variations Related to Headform Type

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A comparison and evaluation of a range of basic anatomic relationships underlying facial form in Angle Class I and Class II dolichocephalic, brachycephalic, mesocephalic, and dinaric types of headform. Interrelated composites of these structural factors and their contributions to different malocclusion tendencies are described.

KEY WORDS: • Cephalic index • Composite analysis • Growth • • Headform • Malocclusion •

Class I, as a discrete and anatomically different type of craniofacial pattern, does not exist. The Class I category of occlusion, in general, represents a heterogeneous assemblage of individuals each having a variable anatomic mix of some mandibular protrusive-causing and mandibular retrusive-causing regional anatomic relationships throughout the face and cranium (Enlow, Kuroda, and Lewis 1971a). Depending on the balance of this mix, a given individual can be more on the Class II or the Class III side within the Class I range.

Corresponding malocclusion effects may be slight to severe, depending on the character and magnitude of these regional relationships and the intrinsic compensatory adjustments occurring during growth.

A broad variety of compensatory or aggravating effects may occur. One example is the Class I individual who has a dominant mandibular retrusive composite of structural features combined with mandibular rami that are anteroposteriorly broad, thus providing a shift toward Class I from what could otherwise be Class II in the childhood craniofacial composite. Converse combinations can occur for Class III (Enlow, Kuroda, and Lewis 1971b, and Enlow 1982).

For these reasons, Classes I and II in this study are categorized as either an *A* or *B* type, in which either the maxillary point A or mandibular point B are protrusive in relation to the other along the functional occlusal plane (Enlow,

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Kuroda, and Lewis 1971a). In the Class I *A* type, regional anatomic relationships with a mandibular retrusive effect predominate, and in Class I *B*, those combinations with a mandibular protrusive effect prevail. If points A and B match, the various regional protrusive/retrusive features are balanced.

Class I *A* shares many anatomical characteristics in common with Class II *A*, including all of the relationships described later in this study. Similarly, Class I *B* individuals are anatomically comparable with the Class II *B*. Both *B* groups are essentially different structural kinds of Class I and II than the *A* groups, and the morphologic basis for treatment rationale can be enhanced by taking these factors into account.

Explanation of Regional Anatomic Relationships

The *counterpart* procedure for headfilm analysis is utilized in this study (Enlow et al. 1971a, Enlow et al. 1971b, Enlow and Pfister 1982, Goldberg and Enlow 1981, and Trouten et al. 1983). This is an anatomic method in which an individuals's craniofacial composite is evaluated within itself for regional morphologic equilibrium.

Most conventional cephalometric analyses depend on comparisons with population norms which are based mostly on anatomically and morphogenically remote planes and angles that are not involved in the direct fitting of anatomic components which constitute the face.

In the counterpart procedure, various key anatomic parts within an individual are compared with each other to determine the regional goodness of fit. Boundaries for the parts are determined by the perimeters of the various major fields of growth, remodeling, and displacement.

The structural effect of each part/counterpart relationship is analyzed for its mandibular/maxillary retrusive or protrusive effect. Vertical effects that affect deep or open bite can also be determined, but are not included in this study (Trouten et al. 1983).

The regional comparisons in the different parts of the craniofacial complex are then evaluated as a whole to determine the aggregate nature of the composite craniofacial construction in that individual.

— Material —

The sample consisted of 264 pairs of lateral and frontal headfilms from the Bolton-Brush files. These included 70 dolichocephalic, 76 brachycephalic, 81 mesocephalic, and 37 dinaric male Caucasians, untreated, ages 14 to 19 years. Sixty-six Class II individuals were also included to determine differences in incidence for Class I *A* and *B* versus Class II *A* and *B* among the headform groups.

The following anatomic relationships were analyzed. Refer to Enlow, Kuroda, and Lewis 1971a and Trouten et al. 1983 for more detailed descriptions of landmarks and construction planes.

Middle cranial fossa

A posterior inclination of the middle endocranial fossae relative to the maxilla has a maxillary retrusive and mandibular protrusive effect. An anterior inclination has a converse effect (Figures 1 and 2). Determination of middle cranial fossa alignment relative to the maxilla and mandible provides a more sensitive appraisal of basicranial influence on facial construction and the positioning of its components than the conventional cranial base angle.

The reasons are that an angular value such as basion-sella-nasion is based on midline points, none of which are involved in the actual articular fitting of basicranium, maxilla, and mandible to each other, or in the anatomic basis for

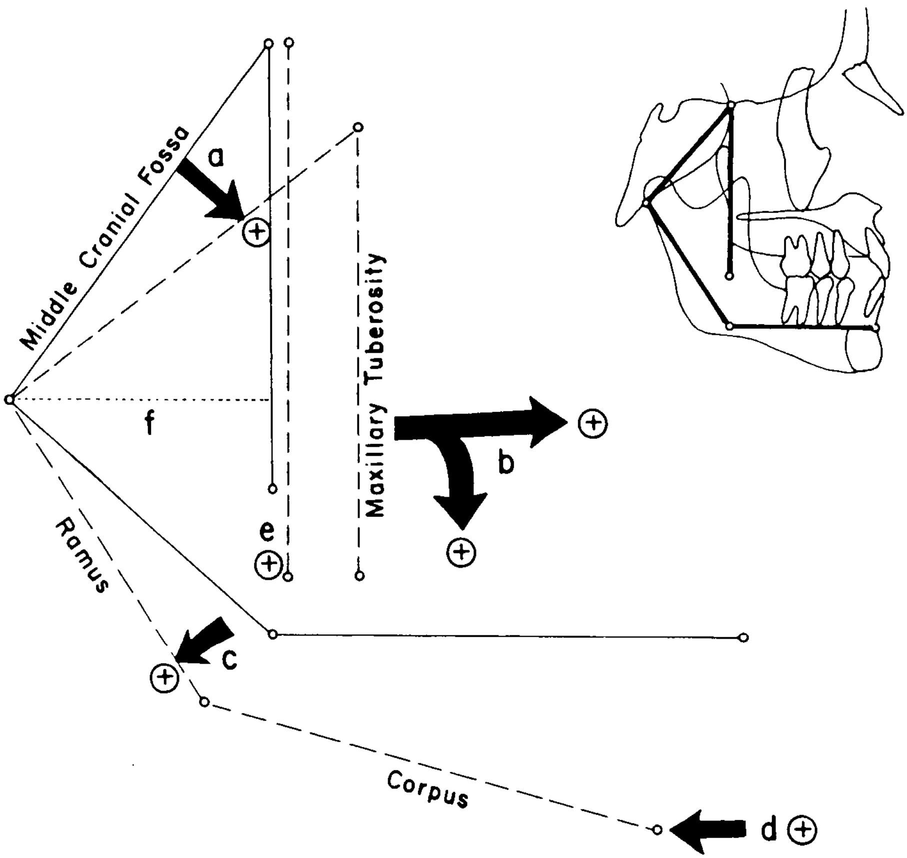

Fig. 1 A forward inclination of the middle cranial fossa (a) has a maxillary protrusive (+) effect (b). Because the maxilla is also lower relative to the condyle, the influence on the ramus would be toward a more downward and backward orientation (c), with a retrusive effect on the mandibular corpus (d).

A long vertical dimension along the posterior part of the maxilla (e) can have a similar retrusive effect on the mandible. If the effects of both a forward middle cranial fossa orientation and vertically long maxilla are combined, the rotational influence on the mandible is compounded.

The breadth of the pharynx (f) is established by the middle cranial fossa and bridged by the ramus, which is an architectural counterpart of the middle cranial fossa.

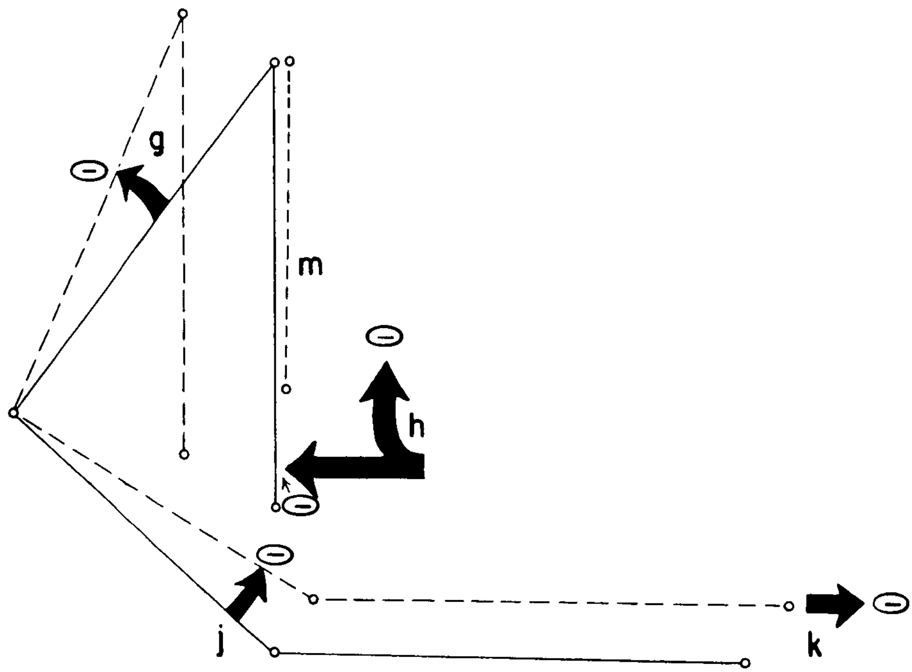

Fig. 2 An upright orientation of the middle cranial fossa (g) has a maxillary retrusive (-) effect (h). The maxilla is raised relative to the condyle, so the ramus can be "rotated" more upward and forward (j), with a protrusive effect on the mandibular corpus (k). A short vertical dimension along the posterior part of the maxilla (m) can have a similar protrusive influence on the mandible.

bilateral positioning among the respective parts; nor do they represent growth sites directly participating in this three-part relationship.

The dolichocephalic headform was found to have a greater frequency for an anterior inclination of the middle cranial fossae (mandibular retrusive), and a lower frequency for a posterior (mandibular protrusive) inclination than the brachycephalic headform ($p < 0.05$, Table 1).

The mesocephalic is intermediate. The dinaric headform, interestingly, shows the highest frequency of all the groups for a posterior inclination (mandibular protrusive), and the lowest frequency for a forward inclination of the middle cranial fossae.

Ramus orientation

A forward orientation of the ramus has a mandibular protrusive effect (Figures 1 and 2). A backward orientation is mandibular retrusive. This relationship is independent of the gonial angle, which measures the orientation of the ramus relative to the corpus and also affects effective mandibular length and corpus position. The gonial angle was not considered in the present study.

Table 1

Distribution percentages for anatomic relationships

The difference between the total of Mandibular Protrusive and Retrusive effects and 100% represents the incidence of a neutral relationship

	DOLICHOCEPHALIC		BRACHYCEPHALIC		MESOCEPHALIC		DINARIC	
	Mandibular Protrusive Effect	Mandibular Retrusive Effect	Mandibular Protrusive Effect	Mandibular Retrusive Effect	Mandibular Protrusive Effect	Mandibular Retrusive Effect	Mandibular Protrusive Effect	Mandibular Retrusive Effect
Middle Cranial Fossa Alignmemt	28	57	50	43	42	49	73	24
Ramus Alignment	19	77	49	47	31	61	27	65
Posterior Maxillary Vertical Height	23	57	46	42	36	59	24	76
Maxillary/Mandibular Arch Lengths	29	69	47	51	21	75	19	70
Ramus Width	60	33	49	50	56	40	57	32
A/B Facial Types	30	52	58	33	22	63	41	51

Table 1

The dolichocephalic headform has a much higher incidence of the mandibular retrusive orientation and a lower frequency of the mandibular protrusive relationship than the brachycephalic ($p<0.05$, Table 1). Both the mesocephalic and dinaric are intermediate in frequency distributions between the dolichocephalic and brachycephalic.

Posterior maxillary vertical height

This relationship compares the vertical height of the nasomaxillary complex relative to the combined heights of the ramus and middle endocranial fossa (Figures 1 and 2). A mandibular retrusive effect is produced by a vertically long maxilla or short ramus/middle cranial fossa. A mandibular protrusive effect results from a short maxilla relative to the ramus/middle cranial fossa.

A greater frequency for a mandibular retrusive effect and a lesser incidence of a protrusive effect in this relationship occurs in the dolichocephalic than in the brachycephalic ($p<0.05$, Table 1). The mesocephalic also tends more strongly toward mandibular retrusion.

The highest incidence of a vertically long midface (mandibular retrusive) is found In the dinaric headform type.

Maxillary and mandibular skeletal arch lengths

This relationship is measured parallel to the functional occlusal plane from points A and B to the maxillary and lingual tuberosities, respectively. This determination is independent of horizontal positioning, because the mandible or maxilla can be placed retrusively or protrusively regardless of relative arch lengths.

The dolichocephalic, mesocephalic, and dinaric groups all show a greater frequency than the brachycephalic for a mandibular bony arch that is short relative to the maxillary bony arch ($p<0.05$, Table 1). The incidence for a longer mandibular arch is higher in the brachycephalic than in the other headform types.

Ramus width

A ramus that is broad anteroposteriorly relative to the pharyngeal space has a mandibular protrusive effect. The pharyngeal space is established by the middle cranial fossae and measured for this purpose from articulare to the maxillary tuberosity, parallel to the occlusal plane.

A narrow ramus has a mandibular retrusive effect. As mentioned above, the ramus and its related composite of growth-pacemaking soft tissues often have a recripocal effect relative to the other retrusive/protrusive relationships considered here. Many Class I individuals, in whom some or all of the other anatomic factors have an aggregate mandibular retrusive effect, develop a broad ramus that provides a measure of compensation helping to offset the other Class II tendencies.

Many Class II individuals also possess a wider ramus, which reduces the severity of the mandibular retrusion. If the offsetting adjustment does not occur, or falls significantly short, the composite Class II condition is more fully expressed.

Class III and prognathic-tendency individuals, conversely, may develop a relatively narrow ramus that minimizes the extent of mandibular protrusion.

In relation to the overall composite, dolichocephalics, mesocephalics, and dinarics all tend toward a composite of anatomic factors that have a mandibular retrusive effect (as described above for the various regional relationships). Brachycephalics, in contrast, tend to have fewer mandibular retrusive and more mandibular protrusive features than the other headform types.

The compensatory capacity of the ramus comes into effect in the higher incidence of a wide ramus, and a lesser frequency for a narrow ramus, in the dolichocephalic and dinaric than in the brachycephalic ($p < 0.05$, Table 1). The brachycephalic has a greater incidence of the narrow and fewer of the wide ramus than the other headform types. The ramus compensation effect is thus operative in the retrusive/protrusive tendencies related to headform differences, particularly for the dolichocephalics, mesocephalics, and dinarics.

A/B Facial Types

The aggregate of all the above morphologic relationships underlies more *A* type faces (mandibular retrusive) and fewer *B* type faces (mandibular protrusive) in the dolichocephalic and mesocephalic headforms than in the brachycephalic ($p < 0.05$, Table 1), which has a converse distribution for *A/B* faces.

The dinaric headform has a high frequency for a mandibular protrusive inclination of the middle cranial fossa and a partially offsetting strong tendency for a vertically long midface. This headform also has more *B* types than the dolichocephalic but more *A* types than the brachycephalic ($p > 0.05$ Table 1).

Class I and II Distribution

More Class I *A* and Class II *A* types were found in the dolichocephalic and mesocephalic headform types than in the brachycephalic or dinaric, which have more *B* and fewer *A* ($p < 0.05$, Table 2). The brachycephalic had the lowest incidence of *A* type.

The composite effects of all the regional anatomic relationships described above contribute to the anatomic basis for these various distribution patterns. It should be noted that while no Class II *B* individuals happened to appear in the present sample for dolichocephalics and dinarics, total absence in the general population should not be assumed.

— Discussion and Summary —

This study presents certain of the contrasting anatomical patterns that characterize the human craniofacial complex associated with different basic headform configurations. These distinctly different combinations in the proportions and fundamental assembly of craniofacial components have not heretofore been fully considered in routine clinical evaluation, and further studies in this regard are encouraged.

Dolichocephalic, Mesocephalic and Brachycephalic

Significantly high incidence of a mandibular retrusive effect, and a much lesser frequency for a mandibular protrusive effect, exists in the dolichocephalic and mesocephalic samples for

1 The inclination of the middle cranial fossae
2 Ramus orientation
3 Relative vertical nasomaxillary length, and
4 Relative bony arch sizes.

The ramus often contributes some degree of compensation.

Table 2

Distribution Percentages for Type A and Type B Faces in Angle Class I and Class II

Incidence of Neutral relationship of points A and B is not shown

	Class I		Class II	
	A	B	A	B
Dolichocephalic	41	37	94	0
Brachycephalic	18	55	53	13
Mesocephalic	60	24	81	12
Dinaric	32	57	100	0

In conjunction with the more narrow width/length ratio of the anterior cranial fossae and the face beneath it in these headforms, this morphologic combination underlies population tendencies for the more leptoprosopic (narrow) type of facial form and Class II tendency that characterize many dolichocephalics and mesocephalics.

In contrast, the incidence of the composite of these same regional morphologic relationships in the brachycephalic tends to be less mandibular retrusive (fewer Class I and II *A* types) than in the dolichocephalic and mesocephalic. Brachycephalics show a greater population tendency for a more euryprosopic (broad) facial pattern with a higher incidence of mandibular or bimaxillary protrusive (*B* type) facial patterns. See Enlow (1982) for a description of topographic facial features relating to headform differences.

The importance of middle cranial fossa configuration in contributing one of many regional factors affecting facial pattern and mandibular or maxillary protrusive/retrusive predispositions has been previously reported (Enlow, Kuroda, and Lewis 1971a, and Enlow 1982). Koenig (1980) reported a high correlation for middle cranial fossa orientation with brachycephalic versus dolichocephalic headform types, utilizing the analytic method employed in the present report. Lavelle (1979) also demonstrated significant headform/basicranial flexure relationships, using the conventional cranial base angle.

Anderson and Popovich (1983) found a range of values for the midline cranial base angle in a sample of individuals all having essentially the same cephalic indexes. Because these investigators did not include a corresponding range of cephalic indexes as specifically found in the different headform types from dolichocephalic through dinaric, their conclusion that they "found no relationship between cranial base flexure and the cephalic index" is not appropriate for the cephalic spectrum, although this was implied. Studies of other investigators cited by Anderson and Popovich, similarly, did not take basicranial differences related to headform into account, but this was not the purpose intended by those investigators.

Based on their own study, Anderson and Popovich also implied that a more closed cranial base flexure does not participate as one regional factor in Class III malocclusion, for the reason that no Class III's occurred in their sample. However, since they did not include any Class III individuals in the entire sample, such a presumption is unjustified. Documentation for a basicranial/Class III relationship does exist (Enlow, Kuroda, and Lewis 1971a, Koenig 1980).

Nasal configuration in the leptoprosopic face tends to be more narrow, protrusive, and sometimes aquiline compared to the typically shorter and wider euryprosopic pug nose. However, many variations in nasal proportion and size exist among the world's different population groups (see later discussion). A short and wide nasal chamber has been shown to have approximate volumetric airway equivalence to the long, narrow nasal form (Koenig 1980).

Phylogenic factors possibly involved in the origins of the dolichocephalic and brachycephalic types of headform have received a great deal of speculative consideration. Environmental temperature, geographic elevation, endocrine physiology, jaw, neck and head muscle actions, tooth design, overall body size, general nutrition, local dietary mineral availability, soft/hard food, and skull balance on the spine are among the underlying factors that have been advanced (Beddoe 1954, Berry and Berry 1967, Ferembach 1956, 1966, Howells 1957, Huizinga and Slob 1965, Males 1938, Messeri 1960, 1966, Milanesi 1966, Newman 1962, Patte 1953,

RIESENFELD 1968, WEIDENREICH 1945, AND COON 1948).

The mesocephalic is intermediate in cephalic and cranial index between the dolichocephalic and brachycephalic types of headform. It is also intermediate for most of the anatomic relationship frequencies considered in this report.

The Dinaric Headform

Because the dinaric type of headform is believed to represent a "partially brachycephalized" dolichocephalic (COON 1948), one objective of the present study was to determine whether the dinaric headform is also intermediate in the same craniofacial context as the mesocephalic. In fundamental respects, however, certain regional anatomic craniofacial relationships in the dinaric were found to be quite different from the mesocephalic.

Facial pattern related to the dinaric headform, described by COON (1948), is typically characterized by exaggerated leptoprosopic features (markedly protrusive, frequently aquiline nose, and very sloping forehead). The anterior cranial fossae, which establish the template for the width and posteroanterior length of the ethmomaxillary complex suspended from them by sutural articulations, retain a more elongate, narrow, dolichocephalic-like proportion in the dinaric. The posterior part of the dinaric head, however, has become "brachycephalized". It is characterized by a distinctive plano-occipital configuration. This occipital (or sometimes lambdoidal) flattening can be quite noticeable, and it results in a significant shortening of the overall anteroposterior cranial dimension.

The cephalic index in the dinaric represents a high width/length ratio that is even more extreme than among most brachycephalics, often hyperbrachycephalic. Accompanying the occipital flattening is bossing of the calvaria on either the posterosuperior part of the skull, or laterally at the right and left parietal areas. This bossing apparently relates to maintenance of endocranial volume. The effect is a distinctive peaking in one or both of the calvarial areas mentioned. The posterior flattening renders the back of the head noticeably closer to the ears, which is useful for the initial recognition of a dinaric head.

If bilateral parietal rather than posterosuperior bossing occurs, the calvaria have a triangular configuration when viewed from the top. In a face-on view, the zygomatic region and posterior parts of the mandible can appear more widened and prominent than in a typical dolichocephalic face, because they grade back onto the more broad lateroposterior parts of the skull. The temporal regions, just lateral and posterior to the eyes, can appear more full in the dinaric head for the same reason.

Two evolutionary factors have been proposed to account for dinaric origins.

One holds that genetic admixtures occurred in the various worldwide geographic interface regions located between early brachycephalic and dolichocephalic population territories (COON 1948). The more narrow dolichocephalic facial complex presumably acted to restrain the evolutionary broadening of the overlying anterior cranial fossa, but the more posterior part of the head became genetically brachycephalized.

The resultant dinaricized headform had multiple and independent geographic and population origins — between the various northern European longhead groups and the middle European round heads (Alpines) and separately, between Alpines and the various Mediterranean and Near East long heads. Sizable concentrations of dinaric populations thus exist today in many parts of France, middle and southern Germany and Poland, northern and middle Italy, Portugal, Armenia, Yugoslavia, and Lebanon. Their origins, however, and possibly certain specific craniofacial morphologic characteristics as well, may differ accordingly.

The second explanation for dinaric origins is that the common Old World practice of infant cradling causes deformation of the back of the head with resultant occipital, lambdoidal, and parietal ontogenic (phenotypic) reconfiguration. COON (1948) held that cradling can markedly augment posterior cranial flattening which would, notwithstanding, still develop to a lesser extent.

EWING (1950), however, concluded that cradling is probably the prevailing cause, although apparently not entirely discounting the genetic factor. He based this on comparisons between Old Country grandparents, having the dinaric headform, and their American-born descendents. The latter, no longer practicing infant cradling, had essentially reverted phenotypically to a more long-headed type.

While this is a compelling observation, the present authors note that the dinaric configuration (though often with the plano-occipital feature not extreme) nonetheless occurs rather frequently in the North-American-born population. A meaningful general percentage is not known, and attempts to determine such a figure could produce misleading results, considering the uneven regional concentrations, variations, and ethnic mixes throughout North America.

Both the Caucasian and Oriental varieties of the round-headed configuration of the brachycephalic headform can apparently also be subject to a dinaric-like redesign. The present authors have noted living individuals with such cranial configurations. This condition, its frequency, and associated craniofacial variations have not yet been investigated.

While both the dinaric and mesocephalic are intermediate headform types, the morphologic basis is different. The dinarics analyzed in the present study, having a more extreme upright alignment of the middle cranial fossa, are thereby more predisposed toward a mandibular-protrusive facial pattern, while a much more retrognathic facial form (Class I *A* type) characterizes the mesocephalics in the sample. A vertically long midface is also more frequent among dinaric individuals.

Individual Variation

It is emphasized that caution must be exercised in applying headform/facial generalizations to any given individual.

First, the distribution of the anatomic features described here represents population tendencies, with wide individual anatomic variations and mixtures of morphologic relationships.

Second, and very importantly, the various long- and round-headed populations around the world, and their mesocephalic and dinaric derivatives, have resulted in part from variably separate and independent early beginnings as well as historically more recent mergers. Intrinsic morphologic and developmental differences likely exist in orthodontically relevant craniofacial features, but such world-wide population-related anatomic variations have not been described more than superficially.

Massive population movements, exchanges, and hereditary admixtures have occurred throughout the long human history, with notable acceleration in recent decades. These have led to virtually limitless craniofacial combinations (COON 1948). An individual dolichocephalic of Nordic descent may differ in a clinically-significant character of craniofacial construction from a Mediterranean, Afghan, or Iranian dolichocephalic. A southern Irish brachycephalic likely differs in certain morphologic characteristics from a Middle European Alpine or an Oriental brachycephalic.

Also, within any more-or-less homogeneous human population, a range for leptoprosopic versus euryprosopic facial features is known to exist. In the predominantly brachycephalic Japanese, for example, many individuals possess the more round-faced, wide-eyed, pug-nosed configuration typically associated with an Oriental population. However, a significant number of individuals demonstrate a more long and narrow nose and narrow eye-set comparable to many Caucasian dolichocephalics. Possible relationships between such facial pattern differences and variations in basicranial configuration have not, to the authors' knowledge, been investigated. The historical origins of Oriental groups and the facial characteristics associated with them, as with Caucasians, have been polyphyletic.

The considerations just outlined point strongly to the appropriateness of individualized determinations of a given person's own craniofacial characteristics as a basis for clinical diagnosis, treatment planning, and appliance selection. The nature of clinical effects on specific regional anatomic relationships and combinations should be known. Presently, however, a comprehensive catalogue of such information is largely unavailable.

A compelling study by DiPalma (1982) showed that different orthodontic appliances have quite different effects on the specific anatomic (not just conventional cephalometric) relationships described in the present report. Different anatomic combinations responded in often contrasting but predictable ways. Such responses were desirable for some patient conditions, but quite contrary to favorable results for others.

Utilization of orthodontic appliances such as the functional regulator and other presumably anatomy-altering tools should be firmly based on much more actual morphologic information and understanding of multifactorial regional morphogenic reactions, than presently exists.

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