Mesh diagram analysis: Developing a norm for African Americans

Margaret M. Faustini, DMD; Cecilia Hale, PhD; George J. Cisneros, DMD, MMSc

Cephalometric analysis has generally involved the use of angular and linear measurements. However, harmony (or disharmony) does not lie within angles, distances, lines, surfaces or volumes; it arises from proportions.[1] Moorrees' mesh analysis has been shown to be a useful technique in that it is a proportionate analysis.[2,3] Since each patient serves as his or her own control, mesh analysis can be used to evaluate any individual's facial imbalance. In addition, both vertical and anteroposterior discrepancies can be assessed simultaneously.

Ethnic variation is a topic frequently discussed but rarely accounted for in cephalometric analyses. Several investigators[4-11] have created normal values for existing cephalometric analyses on selected population samples. Their use, however, has been limited. Presently there is no proportionate analysis available that uses ethnic-specific norms.

The purpose of this investigation was to create a normative mesh diagram for black Americans of African descent. The usefulness of panel selection was evaluated as subjects were reviewed and selected based on a panel's esthetic

Abstract

The mesh analysis is a proportionate cephalometric analysis that enables a patient to serve as his or her own control to create a template from which to assess skeletal, dental, and craniofacial disharmonies. The norms for this analysis were originally created from a white, European American sample. The purposes of this study were: (1) to create a normal mesh diagram from a black, African American population; (2) to compare mesh diagrams from black and white Americans; and (3) to evaluate the usefulness of a panel of diverse members in selecting subjects. All subjects were black Americans of African descent, had no prior orthodontic treatment, and had Class I dental occlusion with minimal crowding (4 mm or less). The panel selected as esthetically pleasing 18 males and 25 females from a group of 77 patients meeting the study criteria. Male and female normal mesh diagrams were created from the cephalographs and compared with Caucasian normal diagrams developed by Moorrees in 1976. Linear and angular components of the hard and soft tissues were compared. Comparisons were also made with previously published normal values. Differences between the African American and Caucasian samples were more notable close to the dentoalveolar complex. Similarities were limited to the soft tissue of the upper face, the cranial base, and the midface. Analysis of the panel selection results did not suggest any trends between or within race, sex, or occupation of the panel members. However, agreement between the races was good.

Key Words

African American norms • Cephalometric analysis • Mesh diagram analysis

Submitted: November 1995 **Revised and accepted:** August, 1996 Angle Orthod 1997; 67(2):121-128.

Table 1
Male and female *t*-test results
African American vs. Caucasian

Landmark	Vertical		Sagittal	
	Male	Female	Male	Female
Soft tissue glabella	NS	X	NS	NS
Soft tissue nasion	NS	NS	NS	
Pronasale	NS	NS	NS	NS
Subnasale	NS	NS	NS	NS
Labrale superior	NS	NS	X	X
Stomion	NS	X	NS	X
Labrale inferior	X	X	X	X
Sulcus labiomentalis	X	X	X	X
Soft tissue pogonion	X	X	X	NS
Glabella	NS	X	NS	NS
Anterior nasal spine	N/A	N/A	X	X
A point	NS	NS	X	X
20 mm up upper 1	X	X	X	X
Tip of upper 1	X	X	X	X
Tip of lower 1	X	X	X	X
20 mm down lower 1	X	X	X	X
B point	X	X	X	X
Pogonion	X	X	NS	NS
Menton	X	X	NS	NS
Orbital margin	NS	NS	NS	NS
PTM	NS	NS	X	NS
Zygomatic process	X	X	X	X'R
PNS	X	X	X	NS
OP (mesial of 5)	X	X	X	X
20 mm up OP	X	X	X	X
Sella	NS	NS	N/A	N/A
Articulare	NS	NS	NS	X
Basion	X	NS	NS	NS
Gonion	X	NS	NS	X
Core rectangle				
Upper facial height (mm)	X			
Anterior cranial base (mm)	NS			

X=Statistically significant difference at alpha=0.05 level
NS=No statistical significance
N/A=Not applicable

judgment. The normal diagram was compared with the Caucasian norms created by Moorrees[12] to assess ethnic variation.

Material and methods

Potential subjects were selected from the records (active and inactive) of patients who started orthodontic treatment between 1986 and 1993 in the Department of Dentistry, Montefiore Medical Center, Bronx, New York. The criteria for inclusion were as follows: complete orthodontic records; ethnic group defined as black Americans of African descent; no history of prior orthodontic treatment; late mixed or permanent dentition; Class I dental occlusion with minimal crowding of 4 mm or less (determined by records including dental casts and space analysis).

Seventy-seven potential subjects were selected (53 females, 24 males). Facial photographs (frontal and profile slides) of all potential subjects were evaluated by a panel of four: one white American female layperson, one black American female orthodontist, one white American male orthodontist, and one black American male layperson. Panel members viewed the photographs and selected esthetically pleasing faces. Subjects were accepted for the study after being selected as esthetically pleasing by at least three of the four panel members.

A sample of 43 subjects (25 females, mean age 13.8 years, and 18 males, mean age 15.0 years) was selected. Each subject's pretreatment cephalograph was traced in natural head position by the principal investigator.[13] The mesh rectangular grid was constructed according to the protocol established by Moorrees in 1976.[12] Normal diagrams were then developed for both males and females.

The mean location of each landmark for both white and black samples was plotted on one diagram after standardizing the black grid to the grid size of Moorrees' Caucasian sample.[12] The black African American norm was compared with the Caucasian norm, landmark by landmark, using two-tailed single sample *t*-tests (0.001 significance level for an overall significance level of 0.05, using the Bonferroni correction for type I error).

Linear and angular cephalometric measurements obtained from subjects' radiographs were compared with cephalometric norms for black African American published in studies by Cotton,[4] Altemus,[6] Drummond,[8] and Richardson and Malholtra[10] by two-tailed single sample *t*-tests (0.0025 significance level for an overall significance level of 0.5, using the Bonferroni correction for type I error).

Measurement of reliability

An initial study of measurement reliability was performed. Ten tracings from the sample population were selected at random for replicate measurements. All measurements were made on a different day than the original data collection. A one-way analysis of variance was

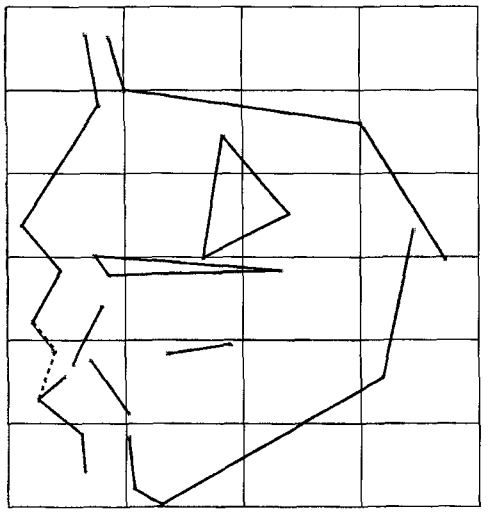

Figure 1

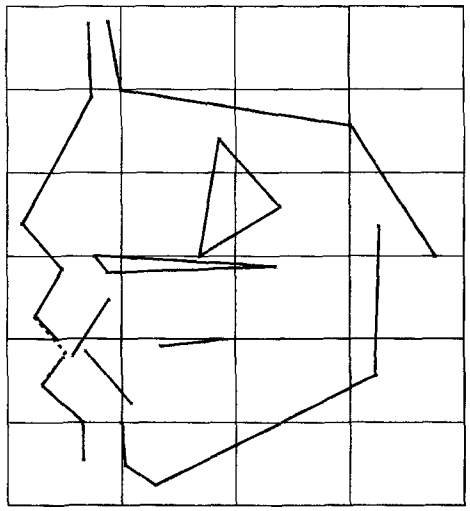

Figure 2

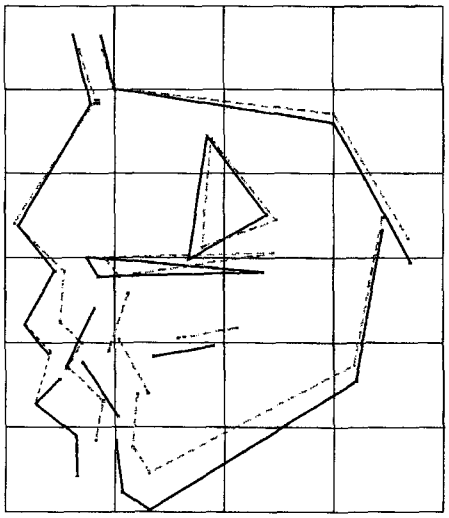

Figure 3

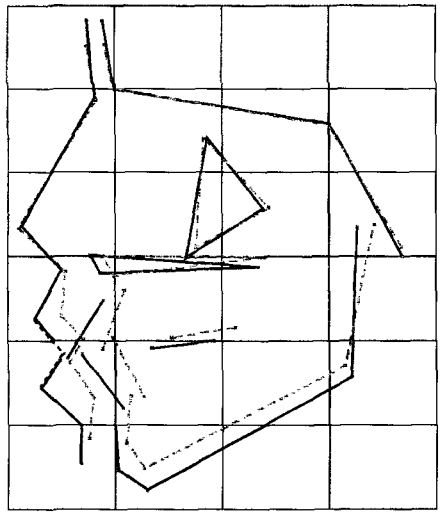

Figure 4

Figure 1
Mesh diagram for a 15-year-old black male.

Figure 2
Mesh diagram for a 13.8-year-old black female.

Figure 3
Mesh diagram for a 15-year-old black male vs. an 18-year-old white male.

Figure 4
Mesh diagram for a 13.8-year-old black female vs. an 18-year-old white female.

used to compare replicate measures. An intraclass correlation coefficient was computed as an estimate of reliability.

Analysis of panel selection

Statistical analysis was performed to assess agreement between panel members. A consensus of esthetic opinion for each of the 77 potential subjects was defined. Agreement was compared by sex, ethnicity, and occupation by calculating kappa statistics.

Results

Data

Table 1 contains the results of the *t*-tests comparing upper facial height, anterior cranial base, and landmark location of the study sample with the Caucasian norms for male and females, respectively, in both vertical and sagittal directions.

Two normative diagrams, male (Figure 1) and female (Figure 2), were produced from the standardized data. Two more diagrams, male (Figure 3) and female (Figure 4), were produced displaying the locations of both the Caucasian and the African American sample means (Figures 1 and 2) superimposed on the Caucasian grid.

Soft tissue and bony facial height

The nasolabial angle was significantly more acute in the African American diagrams. The lower and total soft-tissue facial heights were greater in the black African American diagrams compared with their white counterparts. Upper soft-tissue facial height showed no statistically significant difference between ethnic groups in the vertical direction for either sex. Comparison of the bony facial heights revealed a shorter upper facial height in African Americans in both males and females, longer lower facial heights, and greater nasion-glabella distance.

The lips in the African American diagrams of both sexes were longer vertically and more proc-

Table 2
1994 vs. previous African-American studies
Cephalometric measurements. Male and female *t*-test results

Measurement	Cotton		Altemus		Drummond		Richardson/Malholtra	
Facial angle	NS	NS	NS	NS	*	*	NS	NS
Angle of convexity	NS	NS	NS	NS	*	*	*	*
A-B plane	NS	NS	NS	NS	*	*	*	
Y-axis	NS	NS	NS	NS	*	*	*	X
FMPA	NS	NS	NS	NS	NS	X	NS	NS
IMPA	NS	X	NS	X	*	*	*	
GoGn-SN	*	*	*	*	X	X	*	*
Lower 1 to GoGn	*	*	*	*	NS	X	*	*

X=Statistically significant difference at alpha=0.0025 level (overall alpha=0.05)
NS=No statistical significance
*=Not measured in this study

umbent sagittally, and subnasale and sulcus labiomentalis were located more anteriorly. Lip incompetency was expressed in 72% (13 of 18) of the male subjects and 64% (16 of 25) of the females. Lip incompetency is depicted by a solid line in the diagram, and lip competency is represented with a dashed line.

Midface

In both male and female African Americans, the zygomatic process was located significantly more inferiorly and anteriorly than in Caucasians. The location of the orbital margin showed no statistically significant differences for either sex between ethnic groups. The difference in location of the pterygomaxillary fissure was statistically significant for males in the sagittal plane.

Cranial base

The cranial base flexure of the African American group was more obtuse in both males and females, and the length of the posterior cranial base was greater. There were no statistically significant differences between the lengths of the anterior cranial bases in Caucasian and African American males or females.

Maxilla

The overall length of the maxilla was greater in the African American diagrams for both sexes. The locations of both A-point and ANS were significantly more anterior due to the increased length of the maxilla.

Mandible

The lengths of both the body and the ramus of the mandible were greater in African Americans males and females. A difference between sexes was noted in the gonial angle, with the angle more obtuse in males and more acute in females compared with the respective Caucasian diagrams.

Dentition

The maxillary and mandibular incisors in the diagrams of both male and female African-Americans were more flared in relation to each other and in relation to the palatal plane, mandibular plane, and anterior cranial base in comparison with those in the diagrams of Caucasians. The African American diagrams displayed both procumbent and protrusive incisors compared with Caucasians.

Comparisons with previous studies

Table 2 documents the results of *t*-tests comparing these measurements with normal values from prior studies of African American samples.[4,6,8,10] Of 34 comparisons made, 28 showed no statistically significant differences. A statistically significant difference was shown in comparisons of measurements of incisor angulation in females (with the normal values of Cotton[4] and Altemus[6]) and mandibular plane angle in males and females (with the normal values of Drummond[8]).

Panel selection

Agreement was determined from the data of the panel selection process (Table 3). Kappa interpretation revealed poor agreement for white Americans, orthodontists, males vs. females, and orthodontists vs. nonorthodontists. Agreement was fair for both males and females. Good agreement occurred between black Americans, nonorthodontists, and black Americans vs. whites.

Measurement reliability

The intraclass correlation coefficient was greater than 0.99 for all but one landmark. Thus, very high measurement reliability on all measurements was achieved.

Discussion

The African American and Caucasian diagrams revealed that ethnic differences in the craniofacial complex exist. Overall trends in landmark location in the craniofacial complex documented several obvious differences as well as some similarities between ethnic groups. Similarities were generally limited to the soft tissue of the upper face, cranial base, and the midface. The majority of landmarks located in the dental and alveolar areas displayed statistically significant differences in both the sagittal and vertical directions. These findings were not surprising. In 1980, Richardson[11] concluded that the parameters of the face closest to the dentoalveolar areas show the greatest differences among ethnic groups.

In comparison with previously published cephalometric norms, this study's findings were quite comparable. The statistically significant difference of lower incisor angulation in females to the norms of Cotton[4] and Altemus[6] and the mandibular plane angle to the norms of Drummond[8] may be attributed to the nature of our sample (patients who were seeking orthodontic care).

Since more subjects of both sexes displayed lip incompetency in this study, it was necessary to devise a way to display both lip competence and incompetence in the same diagram. Lip incompetency was represented by a solid line (the norm), and lip competency was represented by a dotted line. Lip incompetency was seen more often in males than in females. Is lip competency an essential component of good facial balance? Drummond proposed that African American patients seemed to have loose, flaccid lips that allowed the teeth to be in balance and harmony in a procumbent position.[8] Ricketts claimed that fullness of the lips, combined with a wide mouth and flaccid lips, is esthetically quite acceptable.[14] In his study of esthetics, environment, and lip relationships, he concluded that the face with wide, full-set lips can function without lip strain, with a normal occlusion, and is "remarkably beautiful."[14] The current data documents that full, incompetent lips can be both esthetically and functionally acceptable. Therefore, in this black African American population, lip incompetency is not a variation from the norm, as it would be in a Caucasian population.

The lips of both sexes in the African American diagrams fell more anterior to or outside the E plane in contrast to the Caucasian group, whose lips fall posterior to or within the E plane. The lips of black males were more protrusive than those females. Sushner[15] demonstrated similar results in 1977. Any differences could be explained by the selection bias in our study, i.e., care-seeking "normative" subjects.

Table 3
Panel selection

1. Females: African American vs. Caucasian	0.05
2. Males: African American vs. Caucasian	0.40
3. African American: Male vs. female	0.69
4. Caucasian: Male vs. female	0.24
5. Orthodontist: Male vs. female	0.35
6. Nonorthodontist: Male vs. female	0.59
7. Male vs. female	0.32
8. African American vs. Caucasian	0.62
9. Orthodontist vs. nonorthodontist	0.33

Clearly, esthetic values established for white patients are neither suitable for nor applicable to black patients. The importance of evaluating African American soft-tissue facial profiles without imposing Caucasian standards is imperative, though understandably difficult given the lack of ethnically appropriate esthetic norms.

This study suggested that a longer lower facial height (bony and soft tissue) was common in African American subjects. Whereas the soft tissue upper facial height was similar to means for Caucasians, the bony upper facial height was less. Altemus documented similar results, i.e., longer lower facial height than upper facial height in his sample of 12- to 16-year-old adolescents in 1960.[6] The nasion-glabella distance was greater in black males and females, consistent with the findings documented in Cameron's 1928 craniometric studies.[16]

The bony components of the midface in African Americans were positioned more anteriorly. This anterior projection of the zygomatic processes in the African American group has been documented by Enlow[17] and was consistent with the maxillary findings. Of the landmarks in the midface, interethnic differences were documented in those located closer to the dentoalveolar areas.

The more obtuse cranial base flexure in African American males and females was consistent with Enlow's findings.[17] Though a longer anterior cranial base in blacks has been demonstrated by Richardson and Malholtra,[18] our

investigation found no statistical significance between ethnic groups. Unfortunately, their study only contained male subjects. A more forward position of A-point and anterior nasal spine on the black African American mesh diagram was consistent with the findings of maxillary prognathism documented by investigators in previous cephalometric studies. Drummond claimed that the primary difference between African American and Caucasian cephalofacial relations was a more anterior placement of the maxilla in African Americans.[8] The mesh diagram clearly documented the increased length of maxilla from ANS to PNS in African Americans.[8] The discrepancy in length of the maxilla between ethnic groups seemed to be attributed to an anteriorly positioned ANS.

Several differences between the two groups were apparent in the mandible. On superimposition, most obvious is the larger body and ramus in African Americans. Increased mandibular body length has been documented by both Altemus[6] and Enlow.[17] Pogonion, menton, and B point were located significantly more inferiorly in the diagrams of African Americans. This could be attributed to the longer lower facial height in males and females, and more obtuse gonial angle in males. The more acute gonial angle in African American females was due in part to the anterior location of articulare.

The mandibular plane angle in the African American diagrams was greater than that in the Caucasian diagrams of both sexes. The mean GoGn to palatal plane and Frankfort horizontal to mandibular plane angles in African Americans were greater than the established Caucasian means of 23 and 21.9 degrees, respectively. Drummond also observed that the mandibular plane angle was steeper in reference to Frankfort horizontal and anterior cranial base in African Americans than in Caucasians.[8] All measurements of skeletal divergence were greater in African American males than in females.

The assessment of the maxillomandibular relationship was compared interethnically using ANB mean values. The ANB difference of 5 degrees was 3 degrees greater than the mean for Caucasians. This value was consistent between the sexes and similar to the findings of Drummond[8] and Richardson and Malholtra.[10] A greater interethnic difference was noted when comparing the SNA angle than the SNB angle. The diagrams clearly depicted the prognathism of both the maxilla and mandible in African American facial form. In comparing the alveolar relationships within the craniofacial complex between the two ethnic groups, the current data support previous researchers' conclusions that the maxilla is positioned more anteriorly relative to anterior cranial base in African Americans. The difference in sagittal position between the maxilla and the mandible was greater in African Americans.

The dental findings in our sample were consistent with the findings of previous investigators. The smaller interincisal angle with protrusive and procumbent incisors found in the African American sample has also been documented by Cotton,[4] Altemus,[6] and Drummond.[8] In comparing cephalometric data for African Americans and Caucasians, Drummond[8] noted that the location and angulation of the dentition (bimaxillary dental protrusion) and the steepness of the mandibular plane angle were most marked.

Sexual dimorphism in craniofacial patterns has been well documented in the literature and is not significantly related to skeletal balance of malocclusion.[20] Consistent between the ethnic groups was the larger dimension of the craniofacial components in males. A striking difference between ethnic groups was noted in measures of skeletal divergency. African American females displayed less skeletal divergency than their male counterparts. However, Moorrees' Caucasian sample showed a similar skeletal divergency in males and females.[12] Behrents' study of growth in the aging craniofacial skeleton revealed increased skeletal divergency in white females in comparison with males.[20]

Panel selection

Evaluation of the data comparing agreement between sexes, ethnicity, and occupation revealed good agreement between ethnic groups, black Americans, and nonorthodontists. This concurs with Martin's observations that white

and black Americans share a common esthetic standard of judging beauty.[21] Poor agreement was found between sexes and occupations. The findings were consistent with investigations that found that improved correlation was dependent upon level of dental education.[22,23] Other studies have documented good agreement between laypersons and dental professionals, including orthodontists.[24,25] However, there appeared to be no consistent pattern in this area, with results varying between studies with regard to panel agreement.

Regarding the usefulness of panel selection, it can only be stated that trends within and between ethnic groups, occupation (orthodontist vs. nonorthodontist), and sexes were variable and inconclusive at best. Though a common basis for esthetic judgment, regardless of sex, occupation, or ethnicity, has been documented, it has yet to be defined and may become more complicated with time. Incorporating a panel selection process in such investigations has become standard.[26] Even though judgment remains variable and difficult to document from study to study, Martin[21] concluded that in the long run, biological mixture and the development of cosmopolitan cultural norms throughout the world would result in a more common standard for judging beauty. Further investigation in this field may assist in defining this common standard of judgment and aid in improving protocol for esthetic selection.

There are some intrinsic deficiencies in our study design, most notably the use of care-seeking patients as the source of our normative data. Clearly, any study using patients who require orthodontic care as the source for normative (ideal) criteria must have its limits. However, there is generally good agreement when one compares our results with previous studies[4,6,8,10] (Table 4). This suggests that our design was sufficient for the task at hand—the establishment of ethnically-appropriate normative data.

As noted throughout our discussion, any differences observed can be attributed to sample selection bias. This has surpassed prior studies, which merely required a Class I occlusion and an orthognathic or straight profile (vaguely defined) as inclusion criteria. Very rarely have esthetics been measured with any objectivity, as was done in this study.

Some might say that it would have been more appropriate to use any of the previous data sets for our study.[4,6,8,10] However, the most recent study[10] reflects upon data that are more than a quarter of a century old and that may not be reflective of the heterogeneity within contemporary African American communities. In short, *normal* is not easy to define, and like beauty, may lie in the eye of the beholder.

The black African American mesh diagrams generated in this study should provide a guide for the clinical evaluation and treatment planning of black patients. As our society becomes more heterogeneous, ethnic-specific cephalometric norms may become more difficult to create and less appropriate for assessing specific populations. But for now our study suggests that norms created for the individual ethnic group should be used by the clinician in the diagnosis and treatment planning of skeletal imbalances and dental malocclusions.

Acknowledgments

Special thanks are extended to Dr. Coenraad Moorrees for his assistance with this paper.

Author Address

Dr. George J. Cisneros
Director, Orthodontics
Dept. of Dentistry
Montefiore Medical Center
111 East 210 St.
Bronx, NY 10467

Margaret M. Faustini, Department of Dentistry, Division of Orthodontics, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, New York.

Cecilia Hale, Department of Biostatistics, Montefiore Medical Center-Albert Einstein College of Medicine, Bronx, New York.

George J. Cisneros, Department of Dentistry, director, Division of Orthodontics, associate professor, Pediatric Dentistry and Orthodontics, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, New York.

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