Original Article

Maxillary Arch Size and Shape in American Blacks and Whites

Benjamin G. Burris, BA[a]; Edward F. Harris, PhD[b]

Abstract: American blacks have larger teeth than whites, but they less frequently exhibit crowding—apparently because of larger arch dimensions. This study quantified differences in arch size and shape in these 2 constituents of the US population. Eighteen dental and bony landmarks were digitized from the maxilla of each of 332 subjects with permanent, intact dentitions, proportionately divided between blacks and whites, men and women. Linear, angular, and area measurements were computer-generated. Arch widths averaged 10% greater in blacks than whites, and mesiodistal arch depths had a greater difference, at 12%. Blacks, with a more square palate and significantly larger palatal index, were distinguished from whites primarily by greater intercanine and interpremolar widths. Arch perimeter was greater in blacks by 8%, and cross-sectional area of the arch was 19% greater in blacks than whites, so blacks and whites differ substantially for these parameters not only in size, but in shape as well. These differences are relevant in prosthodontics and orthodontics since individualization of treatment leads to more effective treatment by working within the patient's natural arch form instead of making patients fit a single standard. (*Angle Orthod* 2000;70:297–302.)

Key Words: Arch size; Arch form; Ethnic differences; Sex differences

INTRODUCTION

American blacks have significantly larger tooth crown dimensions than American whites,[1,2] but, ironically, blacks are less likely to exhibit dental crowding and, actually, are more likely to have spacing between anterior teeth.[3] Blacks have larger arch dimensions that provide ''extra'' space in which teeth can erupt. Not only are arch dimensions larger on average in American blacks, but it also seems that arch form differs, being less parabolic and more square than in whites.[4] These differences can affect clinical treatment. While it is obvious that the dentist treats the individual and not some abstraction of the population, it also holds that people from different ethnic groups present with different modal conditions, and the clinician should anticipate the differences in size and form rather than treating all cases to a single ideal.

The purpose of this study was to quantify the nature of the arch form in a sample of American blacks and whites. The intent was to characterize the difference between ethnic groups (and sexes) in order to identify ways of customizing treatment (eg, prosthodontics, orthodontics) appropriate to the patient's ethnic background.

METHOD AND MATERIALS

Full-mouth dental study casts were obtained from 330 routine dental patients. The sample was composed proportionately of American blacks (n = 171) and whites (n = 159) and of men (n = 164) and women (n = 166). Ethnic affiliation was self-assessed by the patient. Admixture estimates of whites with American blacks are on the order of 20% to 30% for Northern and Western samples[5–8] but are generally below 10% for Southeastern samples.[9–13] All patients had a full complement of natural teeth (excluding third molars), although they were not selected on the basis of occlusion. No patients had been treated orthodontically, although some were treated subsequently. The samples represent a cross-section of routine adolescent and young adult dental patients.

Eighteen buccal cusp tips and incisor line angles were marked on each maxillary dental cast (Figure 1A) and a 1-to-1 ratio print was made, oriented perpendicular to the occlusal surface.[14] Millimetric scales were included in the print to guard against magnification and parallax. The dental landmarks then were digitized as Cartesian coordinates, and mesiodistal arch depths and buccolingual arch widths were computer-generated as straight-line distances between the dental landmarks (Figure 1B,C). Arch depths were measured parallel to the midpalatal raphe, which was defined during data entry.

[a] Dental Student, University of Tennessee, Memphis, Tennessee.
[b] Professor, Orthodontics, Pediatric Dentistry and Community Health, University of Tennessee, Memphis, Tennessee.
Corresponding author: Edward F. Harris, PhD, Department of Orthodontics, College of Dentistry, 875 Union Avenue, University of Tennessee, Memphis, TN 38163
(e-mail: eharris@utmem.edu).

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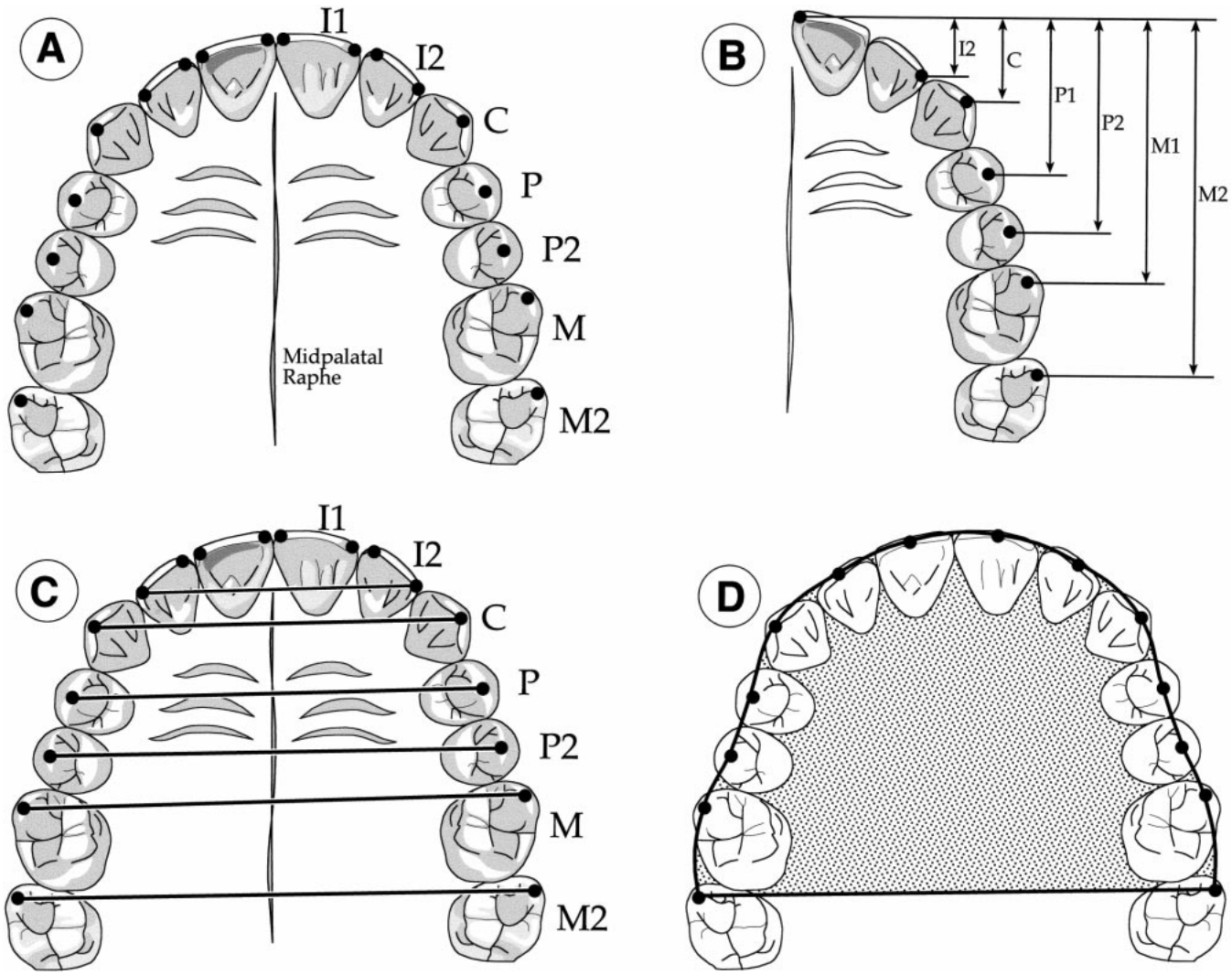

FIGURE 1. Diagrams showing maxillary dental landmarks and arch measurements. (A) Eighteen dental landmarks (buccal cusp tips and incisor line angles) were marked on each cast, along with the midpalatal raphe, prior to making an occlusal print. (B) Six arch depths were calculated (measured parallel to the midpalatal raphe) using the mesial line angle of the central incisor as the anterior limit of the arch. (C) Six arch widths were measured. (D) Cross-sectional arch area was measured by fitting a spline function through 14 points (note that the midpoints of the incisor line angles were used) and a straight line connected the mesiobuccal cusp tips of the second molars. Arch perimeter was the spline distance around the arch (omitting the M2–M2 base).

The set of dental landmarks also was used to fit a curve to each dental arch. Many suggestions of a relevant curve have been put forth in the literature, such as an ellipse, a parabola, and a catenary curve. Lu[15] showed that a close fit with the human dental arch could be obtained with a fourth-order polynomial. Of note, each of the 4 weighting coefficients in the equation is interpretable in terms of an arch's form, namely its left-right asymmetry (terms b_1 and b_3) and its taperedness (b_2) and squareness (b_4). The least-squares best fit was calculated for each arch form, and the 4 regression coefficients were evaluated between races and sexes.

Two other variables, arch perimeter and arch area, were also measured. Perimeter was obtained by plotting the dental coordinates for a case and fitting them with a spline function. A spline is a smooth curve that intersects all of the points. This was accomplished using commercial software (DeltaGraph, DeltaPoint, Monterey, Cal). With the spline function plotted, the base of the dental arch was defined by a line passing through the mesiobuccal cusp tips of the second molars (Figure 1D). This outline (with appropriate scales) was transferred to an image-processing program (NIH Image, Bethesda, Md), where the cross-sectional area was calculated. The area of the arch thus encompasses the dental elements as well as the bony palate, though it does not include the distal portion adjacent to and behind the second molars.

Two-way factorial analysis of variance was used to test for black-white and sex differences in arch size.[16] The distribution of differences was assessed with nonparametric

TABLE 1. Descriptive Statistics and Results of 2-Way Analyses of Variance[a]

	White Male		White Female		Black Male		Black Female		*F* Ratios		
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Race	Sex	Interaction
Arch Widths											
I2 to I2	26.4	2.4	25.4	2.3	28.3	2.7	28.2	2.9	67.3*	3.3	2.4
C to C	33.8	2.7	32.6	2.4	36.7	2.8	35.8	2.7	91.9*	10.8*	0.3
P1 to P1	39.3	3.2	37.7	2.8	43. 4	3.3	42.5	3.2	165.1*	13.8*	1.3
P2 to P2	45.0	3.2	43.1	2.8	48.1	3.8	46.7	3.6	75.7*	16.9*	0.5
M1 to M1	50.1	2.9	48.0	3.2	53.4	3.2	52.3	2.9	126.6*	22.4*	2.9
M2 to M2	55.7	3.1	53.7	2.7	59.0	3.7	57.4	3.3	76.3*	21.1*	0.3
Arch Depths											
I1 to I2	6.7	1.8	6.3	2.2	7.2	1.9	7.0	2.1	6.9*	2.1	0.1
I1 to C	8.4	2.3	8.0	2.2	9.6	2.8	9.3	2.5	17.6*	1.3	0.0
I1 to P1	15.8	2.5	15.1	2.3	17.7	3.2	17.1	2.9	38.1*	4.8	0.0
I1 to P2	22.1	2.8	21.3	2.4	24. 6	3.2	23.9	3.0	58.2*	4.3	0.0
I1 to M1	28.2	2.8	27.2	2.4	31.2	3.5	30.4	3.3	84.9*	6.3	0.1
I1 to M2	38.7	2.9	37.9	2.8	43.0	3.5	41.7	3.6	108.2*	7.2*	0.2
Polynomial Coefficients											
$b_1 \times 10^2$	−2.8	25.4	−4.4	21.5	0.9	34.7	−5.1	31.6	0.1	0.9	0.3
$b_2 \times 10^1$	−9.9	1.6	−9.6	1.3	−11.0	1.9	−10.7	1.8	22.9*	1.2	0.0
$b_3 \times 10^3$	−0.9	3.7	0.3	3.2	−0.3	5.3	0.9	5.4	0.8	3.6	0.0
$b_4 \times 10^3$	4.2	2.3	4.0	2.0	5.0	2.9	5.0	2.6	5.8	0.1	0.1
Arch Surface											
Arch Perimeter	128.6	6.7	125.0	8.6	138.6	6.8	134.5	6.1	94.1*	14.8*	0.1
Arch Area	1,827.8	175.0	1,673.0	179.2	2,135. 7	219.3	2,035.2	168.8	161.6*	23.5*	1.1

[a] Variables are in millimeters, except polynomials, which are unitless, and arch area (mm^2). Sample sizes are listed in the test.
* $P < .01$ (2-tailed).

tests as described in Siegel and Castellan.[17] The alpha level for statistical significance was set at 0.01 to guard against table-wise multiple comparison problems.[18]

RESULTS

Blacks had highly significant larger mean arch widths and depths than whites (Table 1). Arch widths averaged 9% larger in black men than white men, and 11% larger in black women than white women. Indeed, by a signed-ranks test, black and white women were significantly more different than men in the 2 groups ($P = .01$). Additionally, arch depths differed relatively more between races ($\bar{x} = 12\%$) than the transverse widths ($\bar{x} = 9\%$); this length-width difference also achieved significance ($P < .01$). The greatest percentage difference, both for length and breadth, was in the canine and first premolar region, which coincides with blacks having a less-tapered arch form.

These metric differences are apparent when graphed (Figure 2), and it is evident that the black-white difference is much greater than the level of sexual dimorphism within either ethnic group (Figure 3). Percentage-wise, the greatest black-white difference in arch widths is at the first premolars. In blacks, the buccal cusp of the first premolar is lateral of a line defined by the canine and second premolar (Figure 2). In whites, the buccal cusps of the canine and 2 premolars are in approximately a straight line that is more convergent mesially than in blacks. Howes[19] showed that arch width at the first premolar is a practical clinical tool for assessing the taperedness of a dental arch (when the 4–4 width is narrow) vs the broad or square arch (where 4–4 width is broader). It is precisely this feature—relative width at the first premolars—that distinguishes the shape of these black and white dental arches.

Lu[15] showed that a fourth-order orthogonal polynomial produces a close fit with the shape of the human dental arch. The formula is

$$Y = b_1X^1 + b_2X^2 + b_3X^3 + b_4X^4$$

with the odd-numbered terms (b_1 and b_3) defining left-right asymmetry of an arch and the even-numbered terms measuring taperedness (b_2) and squareness (b_4). Asymmetry did not differ by race or sex (Table 1), and 1-sample *t*-tests showed that there was no directional asymmetry in arch form (ie, means of b_1 and b_3 did not differ significantly from zero). This indicates that neither side of the palate is systematically longer than the other. In contrast, Woo,[20] Livshits and Koblyiansky,[21] and others have shown that various craniofacial complexes are characteristically larger on one side of the skull than the other.

Blacks had smaller values for b_2, reflecting their less convergent (more nearly parallel) middle and posterior arch segments. Whites, on the other hand, with a larger value

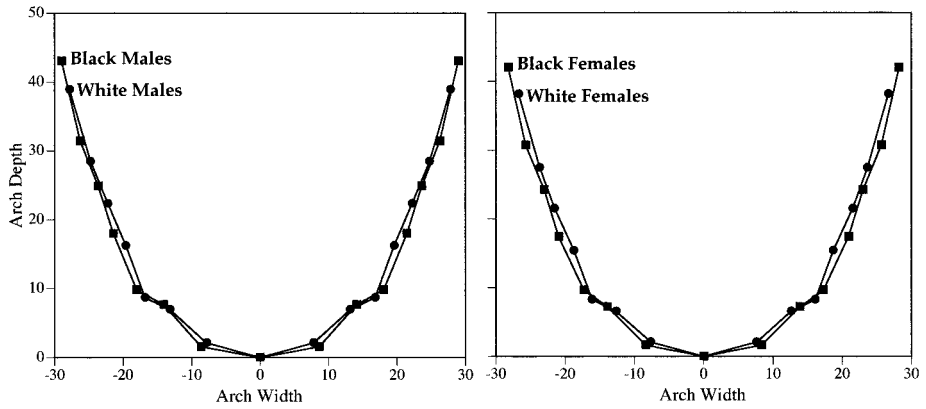

FIGURE 2. Average arch forms for black and white men (left) and women (right). Arches are registered on the mesial limit of the central incisors. From the midpoint backwards, the landmarks are: mesial line angle of the central incisor, distal line angle of the central incisor, distal line angle of the lateral incisor, and then the buccal cusp tips from the canine through the second molar.

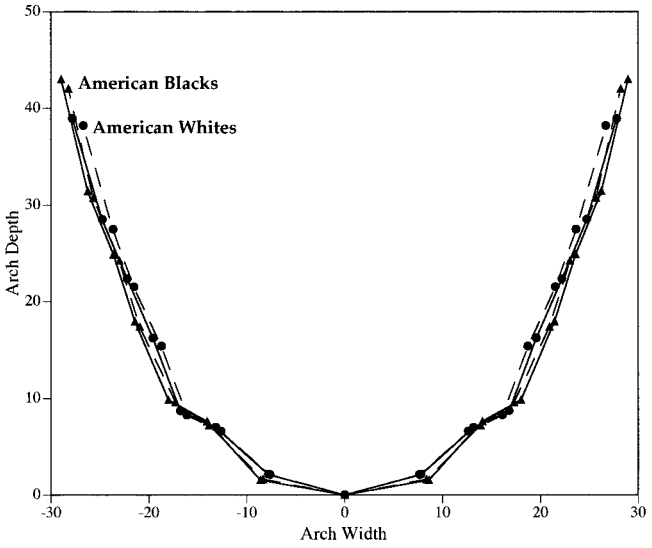

FIGURE 3. Superimposed average arch forms for black and white men and women. Registration is on the mesial line angle of the central incisor. The size difference between men and women within each ethnic group is much less than the difference between blacks and whites. Note that the greatest transverse distance between blacks and whites is at the first premolar.

for b_2, had more rounded arch forms. This is discernible in Figure 3 where all arch widths and depths are smaller in whites, and the black-white difference in widths is greatest in the midarch. The average arch form in whites possessed greater convergence toward the front of the arch than in blacks. The shape of the arch is, however, similar in the pair of sexes within each ethnic group. An ethnic difference in arch form also is suggested by b_4, with a tendency towards more square arches in blacks ($P = .02$).

Since the fitted polynomial indicated that arch form is more tapered in whites than blacks, the palatal index,[22] which is the ratio of arch length to width, should confirm a difference. The ratio of I1-to-M2 length divided by arch width at M2 was expressed as an index by postmultiplying by 100 (Table 2). The black-white difference was highly significant ($P = .0002$). Arch length was a smaller percentage of M2 width in whites, confirming a rounder, less-square arch form. In contrast, there was no suggestion of a sex difference in palatal index within either ethnic group.

This shape difference also can be seen in the ratio of the front of the arch (C to C) expressed as a ratio of the back of the arch (M2 to M2). This width ratio[23] was significantly greater in blacks (Table 2). Blacks have a greater width ratio because, on the average, their arches do not taper as much as in whites. Hence, even using different criteria it is evident that, in addition to greater size, blacks characteristically possess less-tapered arch forms.

As a statistical average, American blacks have appreciably larger tooth crown diameters than American whites,[24] so it is not surprising to find that perimeter of the arch, defined by the buccal cusps and incisor line angles, also is larger in blacks (Table 2). Perimeter was 8% greater in blacks and there was a significant sex difference within each ethnic group (about 3%).

Cross-sectional area of the arch showed the greatest relative black-white difference, at 19%, because it is the cumulative product of the greater arch widths and depths of blacks. Areas exceeded 2000 mm^2 in black men and women, but averaged 1828 mm^2 in white men and 1673 mm^2 in white women.

DISCUSSION

African Americans constitute 12% of the US population, but comparatively little is known about their dental characteristics. On average, blacks have significantly larger arch lengths and widths than American whites (about 10% larger; Figure 2), but the difference is not simply one of larger isometric dimensions. Instead, there also are differences in shape—of proportionality—and the most obvious differences are in the canine-first premolar region. The buccal cusps from the canine through the second premolar define

TABLE 2. Descriptive Statistics and Results of Analyses of Variance of Arch Shape[a]

	White Male		White Female		Black Male		Black Female		*F* Ratios		
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Race	Sex	Interaction
Palatal index	69.3	6.2	70.2	5.1	72.6	6.6	72.5	6.4	13.8*	0.2	0.4
3-3/7-7 ratio	60.7	4.1	60.8	4.5	62.8	5.7	62.5	5.2	8.2*	0.0	0.1

[a] These ratios are unitless. Sample sizes are listed in the text.
* $P < .01$ (2-tailed).

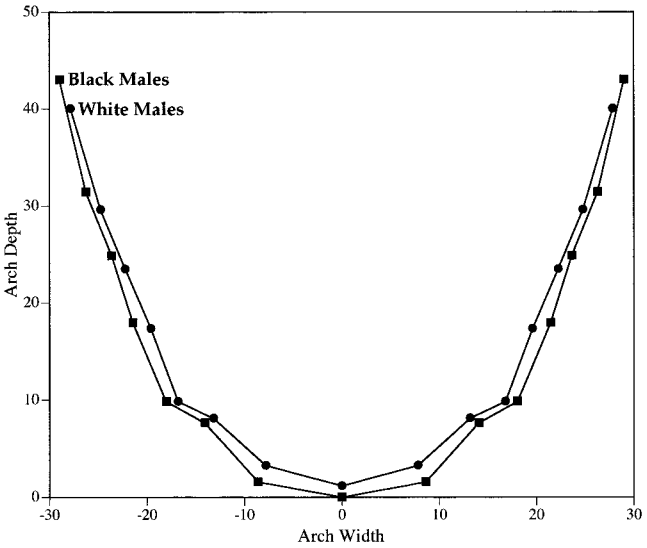

FIGURE 4. Average arch forms for black and white men aligned at the canines to emphasize the greater depth of the anterior segment of the arch in blacks as well as the narrower, more tapered form in whites.

a convex curve in blacks, while the canine and premolars are in an approximately straight line in whites. Figure 4 shows the average black and white arch forms registered at the level of the canines. This highlights how the arch in whites is disproportionately narrow in the canine-first premolar area, and it also shows how these whites define a more rounded arch form since the decrease in radius from the second molar forward is steeper. In contrast, the straighter and less convergent buccal tooth rows in blacks define a more square arch form.

These findings are essentially independent of the patient's age. Teeth remain very close to their erupted positions in the absence of outside forces.[25,26] And, while there is some growth of the intermaxillary and interpalatine sutures,[27,28] the amount of growth is too subtle to detect without long-term longitudinal analysis. That is, in cross-sectional data as analyzed here and in the clinical setting, interindividual variation is considerable while the arch changes within an individual are very small.[29] Therefore, there is no detectable systematic change in arch size or form with age. Indeed, each variable in the present study was regressed on the person's age, but none exhibited anywhere near a statistically significant age effect. The clinical consequence is that the same arch form in the permanent dentition (eg, Figure 2) is equally appropriate irrespective of the patient's age.

Transseptal fibers[30] and the anterior component of force[31,32] maintain tight occlusal contacts and, over the long term, cause the dental arch to become slightly shorter and broader.[33,34] These effects can be detected if the same individuals are followed for a long span of adulthood,[29] but they are obscured in cross-sectional studies where different ages are represented by different individuals.

Various classifications have been developed to characterize arch forms, such as elliptical, parabolic, square, and U-shaped.[35,36] As Jacobson[4] and others note, such schemes are poorly defined and cause confusion within and among studies. The palatal index provides a quantitative sense of arch form. American blacks have a significantly higher palatal index; arch length (I1 to M2) is a greater proportion of molar width (M2–M2) because the buccal tooth rows are more nearly parallel rather than converging as sharply as in whites. This difference also can be appreciated from the width ratio between the canines and second molars, which is a measure of the size gradient between widths at the front and back of the arch (Table 2). The ratio is significantly higher in blacks, again confirming the broader, less-tapered arch form in blacks compared to whites.

CONCLUSION

Arch size is notably larger in American blacks than whites and arch form is squarer and less tapered in blacks in the canine-premolar region. These ethnic differences should be considered during treatment, especially in disciplines such as prosthodontics and orthodontics where arch shape can be modified appreciably.

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