Original Article

A Comparative Study of Caucasian and Japanese Mandibular Clinical Arch Forms

Kunihiko Nojima, DDS, PhD[a]; Richard P. McLaughlin, DDS[b]; Yasushige Isshiki, DDS, PhD[c]; Peter M. Sinclair, DDS, MSD[d]

Abstract: The purpose of this study was to clarify morphological differences between Caucasian and Japanese mandibular clinical arch forms in Class I, II, and III malocclusions. The study included 60 Class I, 50 Class II, and 50 Class III cases from each ethnic group. The most facial portion of 13 proximal contact areas was digitized from photocopied images of the mandibular dental arches. Clinical bracket points were calculated for each tooth based on mandibular tooth thickness data. Four linear and 2 proportional measurements were taken. The dental arches were classified into square, ovoid, and tapered forms to determine and compare the frequency distributions between the 2 ethnic groups. The Caucasian population had a statistically significant decreased arch width and increased arch depth compared with the Japanese population. When the subjects were regrouped by arch form, no statistically significant difference in arch dimension was observed between the 2 ethnic groups in any of the arch form samples. Our results suggest that there is no single arch form specific to any of the Angle classifications or ethnic groups. It appears to be the frequency of a particular arch form that varies among Angle classifications or ethnic groups. (*Angle Orthod* 2001;71:195–200.)

Key Words: Dental arch form; Angle classification; Ethnic difference

INTRODUCTION

Although a number of researchers have attempted to identify an arch form unique to a certain ethnic group, most of their studies compare average clinical arch forms derived from normal untreated samples[1–5] or research arch forms established by measuring arch dimensions using the incisal edges and cusp tips as landmarks.[6–15]

From the standpoint of clinical orthodontics, however, not only does the determination of the patient's posttreatment arch form help meet esthetic requirements but it also is vital for long-term occlusal stability. Based on previous studies on relapse, it is generally agreed that postorthodontic occlusal stability is enhanced through maintenance of the original mandibular intercanine width and preservation of the original arch form.[16–19]

[a] Assistant Professor, Department of Orthodontics, Tokyo Dental College, Chiba, Japan.

[b] Clinical Professor, Department of Orthodontics, University of Southern California, Los Angeles, Calif.

[c] Professor and Chairman, Department of Orthodontics, Tokyo Dental College, Chiba, Japan.

[d] Professor and Chairman, Department of Orthodontics, University of Southern California, Los Angeles, Calif.

Corresponding author: Dr Kunihiko Nojima, 1-2-2 Masago Mihama-ku, Chiba 261-8502, Japan
(e-mail: nojima@tdc.ac.jp).

Accepted: December 2000. Submitted: March 2000.

Little,[20] based on more than 35 years of research, recommended as a clinical guideline that the patient's pretreatment arch form be used as a guide to posttreatment arch shape. The application of a single ideal arch form to every member of an ethnic group, despite individual variations, may adversely affect posttreatment occlusal stability.[4,21–23]

Meanwhile, with the recent advancements in elastic wire materials and preadjusted appliance systems, preformed arch wires have been commercially available and frequently used, mainly in the leveling and alignment stage. However, their superelastic property makes customization of arch form and size difficult. Clinically, it seems more reasonable to have several types of preformed arch wires available and to select the shape that most closely matches the patient's pretreatment arch form according to his or her ethnicity and type of malocclusion.

This study was designed to clarify morphological differences between the Caucasian and Japanese clinical mandibular arches in Class I, Class II, and Class III malocclusions by measuring their arch dimensions. Furthermore, the subjects were regrouped into tapered, ovoid, and square arch forms to determine the frequency distribution of the 3 arch forms for comparison between the ethnic groups in each Angle classification.

MATERIALS AND METHODS

The Caucasian cases included pretreatment mandibular dental models of 60 Class I, 50 Class II, and 50 Class III

TABLE 1. Sample Characteristics

	Caucasian					Japanese				
Sample	n	Males	Females	Mean Age (Years)	SD (Years)	n	Males	Females	Mean Age (Years)	SD (Years)
Class I	60	23	37	16.6	5.9	60	27	33	16.3	3.3
Class II	50	26	24	14.7	4.7	50	20	30	16.8	4.2
Class III	50	27	23	14.5	4.3	50	23	27	16.8	3.9
Total	160	76	84	15.4	5.2	160	70	90	16.6	3.8

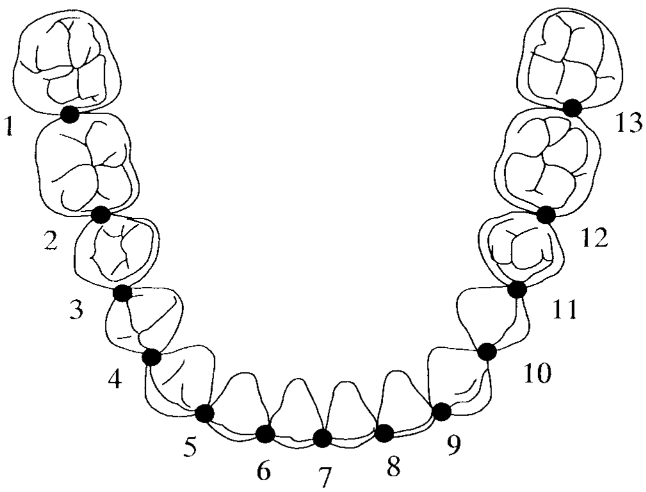

FIGURE 1. Points digitized on occlusal photocopy. These points represent the most facial portions of 13 proximal contact areas.

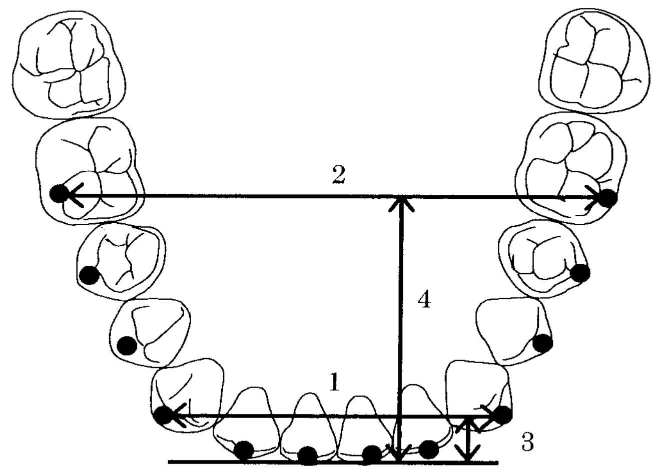

FIGURE 2. Twelve clinical bracket points and 4 linear and 2 proportional measurements of arch dimensions. 1, intercanine width; 2, intermolar width; 3, canine depth; 4, molar depth; 5, canine W/D ratio; and 6, molar W/D ratio.

cases from the University of Southern California, Department of Orthodontics, and a private practice in San Diego, Calif. The Japanese cases included 60 Class I, 50 Class II and 50, Class III cases from Tokyo Dental College, Department of Orthodontics (Table 1). All cases were subjected to the following inclusion criteria: (1) Class I, II, and III malocclusions of a dentoalveolar nature, (2) permanent dentitions with normal tooth size and shape, (3) a 3 mm or less arch length discrepancy, and (4) without restorations extending to contact areas, cusp tips, or incisal edges.

The occlusal surfaces of the mandibular models were photocopied with a ruler included for magnification correction. The photocopied images were placed on a digitizer and the most facial portions of 13 proximal contact areas around the arch were digitized (Figure 1). These points are used to estimate corresponding bracket slot locations (clinical bracket point) for each tooth. The proximal contact between the 2 central incisors was used as the origin of the XY coordinate. The original XY coordinate on the digitizer was corrected for magnification and adjusted to establish a new X′Y′ coordinate in such a way that the mean inclination of straight lines connecting the right and left contact points between the first and second premolars and those between the second premolar and first molar became parallel to the original X axis. The perpendicular to a line connecting mesial and distal contact points of each tooth on the coordinate was drawn from the midpoint of the mesiodistal line for the incisors, canines, and premolars and from the mesial third of the line for the molars. The perpendicular was extended labially or buccally to locate a clinical bracket point for each tooth based on the mandibular tooth thickness data of Andrews.[24]

The following 4 linear and 2 proportional measurements were taken (Figure 2):

- intercanine width: the distance between the canine clinical bracket points
- intermolar width: the distance between the first molar clinical bracket points
- canine depth: the shortest distance from a line connecting the canine clinical bracket points to the origin between the central incisors
- molar depth: the shortest distance from a line connecting the first molar clinical bracket points to the origin between the central incisors
- canine W/D ratio: the ratio of the intercanine width and the canine depth
- molar W/D ratio: the ratio of the intermolar width and the molar depth.

In addition, 12 clinical bracket points per patient were printed at full size to select from square, ovoid, and tapered arch forms (OrthoForm, 3M Unitek, Calif) the arch form that best fit the 8 clinical bracket points from first premolar to first premolar (Figure 2).

The means and standard deviations were calculated for each sample. Ethnic differences in arch dimensions were analyzed by unpaired *t*-tests and differences in frequency distribution of the 3 arch forms were analyzed using the chi-square test. In addition, the subjects were regrouped into the 3 arch form samples to recalculate means and standard deviations for statistical analysis by unpaired *t*-tests. The levels of significance used were $P < .01$ (**) and $P < .05$ (*), where $P \geq .05$ was considered not significant (NS).

The measurement error was assessed by statistically analyzing the difference between duplicate measurements taken at least 2 weeks apart on 24 casts selected at random. The measurement errors were generally small (less than 5% of the measured mean value) and within acceptable limits.

RESULTS

Table 2 depicts the arch dimension measurements and results of the *t*-test for the Caucasian and Japanese Class I, II, and III samples. The Caucasian group showed significantly smaller intercanine width, intermolar width, and molar W/D ratio in all 3 Angle classifications. In addition, the Caucasian group also showed a significantly smaller canine W/D ratio in Class I and Class II malocclusions and significantly larger canine and molar depths in Class I and Class III malocclusions than the Japanese group. When Class I, II, and III malocclusions were combined, statistically significant differences were observed in all the measured variables between the Caucasian and Japanese ethnic groups.

Table 3 shows the frequency distributions of the 3 arch forms and the results of the chi-square test for the Caucasian and Japanese groups. In the Caucasian Class I sample, ovoid and tapered arch forms were almost equally distributed, accounting for more than 90% of the sample, while the square arch form was rarely seen. In contrast, a square arch form was observed in more than 50% of the Japanese Class I arches, with a combined frequency of square and ovoid arch forms exceeding 90%. Sixty percent of the Caucasian Class II arches displayed a tapered arch form, with most of the remainder showing an ovoid arch form. The frequency of the ovoid arch form among the Japanese Class II arches was over 50%, with square and tapered shapes accounting for approximately 25% each. In the Caucasian Class III sample, the 3 arch forms were almost evenly distributed, with square arch forms found at the highest frequency of over 40%. Almost all the Japanese Class III arches were of either square or ovoid shape, the former accounting for over 50%.

All the Class I, II, and III samples demonstrated statistically significant differences in frequency distribution of the arch shapes between the 2 ethnic groups. When all 3 Angle classifications were combined, nearly 50% of the Caucasian patients exhibited a tapered arch form, with over 80% of them showing either tapered or ovoid arch form. Almost 90% of the Japanese cases demonstrated either square or ovoid arch forms, with both arch forms being almost equal in frequency.

Table 4 depicts the arch dimension measurements and results of *t*-test obtained by regrouping the subjects into square, ovoid, and tapered arch form samples. Both ethnic groups showed increasing intercanine width, intermolar width, canine W/D ratio, and molar W/D ratio and decreasing canine and molar depths as the mandibular arches changed in form from square to ovoid to tapered. Regardless of arch form, the Caucasian arches tended to be narrower and deeper than the Japanese arches while the canine W/D ratios of the 2 ethnic groups were almost equal. No statistically significant difference was observed in any of the variables measured.

DISCUSSION

In the present study, a clinical bracket point corresponding to a bracket slot point was mathematically estimated from the most facial portion of the proximal contact area for each tooth and used as a landmark for mandibular arch form assessment in Class I, Class II, and Class III malocclusions. Many of the conventional studies included normal untreated samples for determining arch form mathematically[1–5] or for characterizing arch form through various measurements using the incisal edges and cusp tips as landmarks.[6–15] While this methodology may suffice for anthropological arch form assessment and comparison among different ethnic groups, it may be inappropriate from the standpoint of posttreatment occlusal stability to clinically apply data obtained in these studies to edgewise orthodontic treatment of malocclusions. Not only did our results clarify ethnic differences in arch form between the Caucasian and Japanese but they also seem to offer a great clinical value for modern orthodontics with the frequent use of preformed superelastic arch wires.

Regardless of Angle classification, the Caucasians showed narrower arch forms than those of the Japanese, with approximately 1 mm less mean intercanine width and 1.5 mm less intermolar width. Differences among Angle classifications were observed in arch depth, however, with a statistically significant ethnic difference in canine depth in the Class I sample and in molar depth in the Class III sample.

There was no ethnic difference in the canine W/D ratio in the Class III sample nor in the anterior curvature. These results clearly indicate that Caucasians have narrower and deeper arch forms in both canine and molar regions than Japanese. Aoki et al[6] reported similar findings. In their study, the transverse width of the canines and molars was

TABLE 2. Comparison of Variables Between Caucasian and Japanese for Class I, II, and III Samples[a]

	Class I Sample					Class III Sample				
	Caucasian (n = 60)		Japanese (n = 60)			Caucasian (n = 50)		Japanese (n = 50)		
Variable	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value
Intercanine width (mm)	29.01	1.26	29.90	1.52	.0007**	28.92	1.22	30.04	1.30	<.0001**
Intermolar width (mm)	49.17	2.29	50.71	2.81	.0014**	48.50	2.53	50.38	2.95	.0009**
Canine depth (mm)	6.30	0.88	5.66	1.01	.0003**	6.79	1.12	6.40	0.88	.0559 NS
Molar depth (mm)	26.84	1.62	26.28	1.94	.0859 NS	27.43	1.97	27.29	1.68	.7024 NS
Canine W/D ratio	4.68	0.56	5.43	0.87	<.0001**	4.37	0.70	4.79	0.70	.0036**
Molar W/D ratio	1.84	0.11	1.94	0.15	<.0001**	1.78	0.16	1.85	0.15	.0146*

[a] **, $P < .01$; *, $P < .05$; NS, not significant.

greater for the Japanese than for the Caucasian, while the ratio of the antero-posterior length to the canine width was larger for the Japanese than for the Caucasian.

In general, the dolichocephalic head form is commonly seen among Caucasians, while Japanese are mostly brachycephalic.[25] It is conceivable that the racial difference in head form is closely related to arch width and depth, as suggested previously.[10,11] Although males have a larger arch size than females, it is generally agreed that there is no gender difference in arch form.[7,8,26] For this reason and because of similar male-to-female ratios in both ethnic groups, no analysis was made of gender differences in arch form in this study.

Braun et al[27] stated in their report on differences in arch dimensions between Angle classes that the Class II mandibular arches exhibited generalized reduced arch width and depth compared with the Class I arches and that the Class III mandibular arches had smaller arch depth and greater arch widths than the Class I arches. Our results showed that the Class I arches were deeper than the Class II arches, with little difference in arch width between the 2 in either ethnic group, and that Class II arches had the smallest canine and molar W/D ratios, followed by Class I arches and then by Class III arches. The minimal arch width difference observed between the Class I and Class II arches seems to be due to a more tapered anterior curvature of the Class II arches, causing the canines to be positioned more distally where the intercanine width is almost as wide as that of the Class I arches. The Class III arches were the widest and the shallowest. The present study was able to characterize differences in the morphology of mandibular arches by ethnicity and Angle classification through measurement of arch dimensions and comparison of the mean values.

However, the analysis of frequency distribution of the 3 arch forms in the Class I arches revealed the predominance of ovoid and tapered arch forms in the Caucasian population and of square and ovoid arch forms in the Japanese population. The frequency of narrower arch forms was higher in the Caucasian population. Felton et al[22] reported that there was little difference between the arch forms of the Class I and Class II malocclusion groups. In the present study, however, the Class II arches in the Caucasian group were associated with a decreased frequency of ovoid arch form and an increased frequency of tapered arch form. The Japanese group showed increased frequencies of ovoid and tapered arch forms and a decreased frequency of square arch form, showing a tendency to shift to narrower arch forms in both ethnic groups.

For the Class III arches, on the other hand, the frequency of square arch form was the highest in both groups, followed by ovoid and then by tapered arch forms. The much smaller, though statistically significant, ethnic difference in frequency distribution of arch forms among the Class III arches seems to indicate less influence of ethnicity on Class III mandibular dentition. This can be explained by the common pathogenesis of Class III malocclusion and the resultant dental compensation by lingual tipping of the mandibular anterior teeth, causing the anterior part of the mandibular arch to flatten.

With all 3 Angle classifications combined, more than 80% of the Caucasian had ovoid and tapered arch forms and more than 80% of the Japanese had ovoid and square arch forms. Considering the difference in incidence of each type of malocclusion between the 2 ethnic groups,[25] actual racial differences in frequency distribution of the arch forms may be even more pronounced than those found in this study. That is, the frequency of tapered arch form may further increase with a decreased frequency of square arch form in Caucasian patients while the opposite may be true for Japanese patients.

The comparison of arch dimensions by regrouping the subjects by arch form revealed no statistically significant difference in any of the measured variables between the 2 ethnic groups, though the Caucasians tended to have smaller intercanine widths and larger canine depths than the Japanese. However, the canine W/D ratios of the 2 ethnic groups were almost identical, indicating that anterior curvatures of their dental arches are also very similar. Our results showed that, despite differences in frequency distribution of the arch forms between the Caucasian and the Japanese, there was no racial difference within each arch form type.

TABLE 2. Extended

Class III Sample					Total				
Caucasian (n = 50)		Japanese (n = 50)			Caucasian (n = 160)		Japanese (n = 160)		
Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value
29.29	1.68	30.25	1.43	.0025**	29.07	1.39	30.05	1.42	<.0001**
50.62	2.65	51.87	2.59	.0189*	49.42	2.61	50.97	2.84	<.0001**
5.69	1.15	5.63	0.93	.7814 NS	6.26	1.13	5.88	1.00	.0016**
27.02	2.59	26.07	1.71	.0324*	27.08	2.07	26.53	1.86	.0123*
5.34	1.00	5.51	0.89	.3645 NS	4.79	0.85	5.25	0.88	<.0001**
1.89	0.21	2.00	0.17	.0057**	1.84	0.17	1.93	0.17	<.0001**

TABLE 3. Comparison of Frequency Distribution of Square, Ovoid, and Tapered Arch Forms Between Caucasian and Japanese[a]

	Caucasian						Japanese						
	Square		Ovoid		Tapered		Square		Ovoid		Tapered		
Sample	n	%	n	%	n	%	n	%	n	%	n	%	*P* Value
Class I	5	8.3	27	45.0	28	46.7	32	53.3	23	38.3	5	8.3	<.0001**
Class II	2	4.0	18	36.0	30	60.0	12	24.0	26	52.0	12	24.0	.0002**
Class III	22	44.0	16	32.0	12	24.0	29	58.0	19	38.0	2	4.0	.0153*
Total	29	18.1	61	38.1	70	43.8	73	45.6	68	42.5	19	11.9	<.0001**

[a] **, *P* < .01; *, *P* < .05.

TABLE 4. Comparison of Variables Between Caucasian and Japanese for Square, Ovoid, and Tapered Arch Form Groups[a]

	Square					Ovoid					Tapered				
	Caucasian (n = 29)		Japanese (n = 73)			Caucasian (n = 61)		Japanese (n = 68)			Caucasian (n = 70)		Japanese (n = 19)		
Variable	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value	Mean	SD	Mean	SD	*P* Value
Intercanine width (mm)	29.96	1.69	30.61	1.55	0.0656 NS	29.37	1.34	29.77	1.07	0.0607 NS	28.44	0.97	28.92	1.04	0.0613 NS
Intermolar width (mm)	52.24	2.01	52.65	2.59	0.4482 NS	49.81	2.27	49.85	2.15	0.8991 NS	47.90	1.95	48.49	2.20	0.2582 NS
Canine depth (mm)	5.26	1.11	5.36	0.96	0.6868 NS	6.05	0.76	6.15	0.81	0.4524 NS	6.85	1.06	6.89	0.61	0.8873 NS
Molar depth (mm)	26.16	2.71	26.03	2.03	0.7933 NS	27.02	1.78	26.86	1.63	0.5895 NS	27.52	1.90	27.27	1.42	0.5967 NS
Canine W/D ratio	5.86	0.92	5.84	0.83	0.9446 NS	4.91	0.48	4.90	0.52	0.9257 NS	4.24	0.57	4.23	0.33	0.9387 NS
Molar W/D ratio	2.02	0.19	2.03	0.16	0.6403 NS	1.85	0.12	1.86	0.12	0.5328 NS	1.75	0.12	1.78	0.09	0.2747 NS

[a] NS, not significant.

CONCLUSION

Engel[28] classified human arches into 9 shapes and Raberin et al[4] into 5 shapes in an attempt to cope with the great variability in arch form encountered in clinical practice. In the present study, mandibular arches were classified into square, ovoid, and tapered arch forms in order to determine the frequency distribution of the 3 arch forms for each ethnic group. As a result, no statistically significant difference was found between the 2 ethnic groups within each arch form sample, suggesting that it may be acceptable to classify patients' dentitions into the 3 arch forms. Our results made it clear that there is no single arch form unique to any of the Angle classifications or ethnic groups and that it is the frequency of a particular arch form that varies between the ethnic groups or among Angle classifications. This study suggests the usefulness of determining each patient's arch form based on the pretreatment mandibular dental model in order to achieve posttreatment esthetics and occlusal stability.

REFERENCES

1. Braun S, Hnat WP, Leschinsky R, Legan HL. An evaluation of the shape of some popular nickel titanium alloy preformed arch wires. *Am J Orthod Dentofac Orthop.* 1999;116:1–12.
2. Choi S. An orthodontic study of the teeth and dental arch form of Koreans with normal occlusion. *Shikwa Gakuho.* 1984;84:1055–1076.
3. Kosaka H, Kobayashi T. A study of dental-arch forms and orthodontic arch-wire forms in Japanese subjects with normal occlusion. *Shikwa Gakuho.* 1997;97:1029–1036.
4. Raberin M, Laumon B, Martin J, Brunner F. Dimensions and form of dental arches in subjects with normal occlusions. *Am J Orthod Dentofac Orthop.* 1993;104:67–72.
5. Sebata E. An orthodontic study of teeth and dental arch form on the Japanese normal occlusions. *Shikwa Gakuho.* 1980;80:945–969.

6. Aoki H, Tsuta A, Ukiya M. A morphological study and comparison of the dental arch form of Japanese and American adults: detailed measurements of the transverse width. *Bull Tokyo Dent Coll.* 1971;12:9–14.
7. Collins BP, Harris EF. Arch form in American blacks and whites with malocclusions. *J Tenn Dent Assoc.* 1998;78:15–18.
8. Ferrario VF, Sforza C, Miani A Jr, Taraglia G. Mathematical definition of the shape of dental arches in human permanent healthy dentitions. *Eur J Orthod.* 1994;16:287–294.
9. Goose DH. Maxillary dental arch width in Chinese living in Liverpool. *Arch Oral Biol.* 1972;17:231–233.
10. Kasai K, Kanazawa E, Aboshi H, Richards LC, Matsuno M. Dental arch form in three Pacific populations: a comparison with Japanese and Australian aboriginal samples. *J Nihon Univ Sch Dent.* 1997;39:196–201.
11. Koyoumdjisky-Kate E, Zilberman Y, Zeevi Z. A comparative study of tooth and dental arch dimensions in Jewish children of different ethnic descent; I. Kurds and Yemenites. *Am J Phys Anthropol.* 44:437–444.
12. Lee B. Anthropological studies on the Korean mouth. 1. The size of dental arch. *Shikwa Gakuho.* 1977;77:905–923.
13. Mack PJ. Maxillary arch and central incisor dimensions in a Nigerian and British population sample. *J Dent.* 1981;9:67–70.
14. Merz ML, Isaacson RJ, Germane N, Rubenstein LK. Tooth diameters and arch perimeters in a black and a white population. *Am J Orthod Dentofacial Orthop.* 1991;100:53–58.
15. Nummikoski P, Prihoda T, Langlais RP, McDavid WD, Welander U, Tronje G. Dental and mandibular arch widths in three ethnic groups in Texas: a radiographic study. *Oral Surg Oral Med Oral Pathol.* 1988;65:609–617.
16. Artun J, Garol JD, Little RM. Long-term stability of mandibular incisors following successful treatment of Class II, division 1, malocclusions. *Angle Orthod.* 1996;66:229–238.
17. De La Cruz AR, Sampson P, Little RM, Artun J, Shapiro PA. Long-term change in arch form after orthodontic treatment and retention. *Am J Orthod Dentofac Orthop.* 1995;107:518–530.
18. Gardner SD. Chaconas SJ. Posttreatment and postretention changes following orthodontic therapy. *Angle Orthod.* 1976;46:151–161.
19. Shapiro PA. Mandibular arch form and dimension. *Am J Orthod.* 1974;66:58–70.
20. Little RM. Stability and relapse of dental arch alignment. *Br J Orthod.* 1990;17:235–241.
21. Currier JH. A computerized geometric analysis of human dental arch. *Am J Orthod.* 1969;56:164–179.
22. Felton JM, Sinclair PM, Jones DL, Alexander RG. A computerized analysis of the shape and stability of mandibular arch form. *Am J Orthod Dentofacial Orthop.* 1987;92:478–483.
23. White LW. Individualized ideal arches. *J Clin Orthod.* 1978;12:779–787.
24. Andrews LF. *Straight Wire—The concept and appliance.* San Diego, Calif: LA Wells Co; 1989.
25. Enlow DH. *Handbook of Facial Growth.* 3rd ed. Philadelphia, Penn: WB Saunders Company, 1990;193–221.
26. DeKock WH. Dental arch depth and width studied longitudinally from 12 years of age to adulthood. *Am J Orthod.* 1972;62:56–66.
27. Braun S, Hnat WP, Fender DE, Legan HL. The form of the human dental arch. *Angle Orthod.* 1998;68:29–36.
28. Engel GA. Preformed arch: reliability of fit. *Am J Orthod.* 1979;76:497–504.