Dental Arches in Various Ethnic Groups

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Introduction

It is well recognized that different ethnic groups of man show variations in the size and shape of the dental arch. For instance, Aitchison[1], in a qualitative survey of the dental arches from Negroid, Mongoloid, Caucasoid, Asiatic Indian and Australian aboriginal skulls, has shown that differences exist between these races quite apart from the variation between individuals within the various racial groups.

Quantitative studies of size and shape of the dental arch have, in the main, been confined to single ethnic groups. For instance, reports of measurements of the dental arches have been made by Campbell[4], and Brown, Barrett and Darroch[3] on Australian aborigines, by Moorrees and Reed[15], Moorrees[14], Knott[12], and Holcomb and Meredith[10] on North American Caucasoids, by Seipel[17] on Scandinavians, by Dockrell, Clinch and Scott[5] on Arran Island Europeans, by Moss and Chase[16] on Liberian Negroids and by Foster, Hamilton and Lavelle[6] on British Caucasoids. Comparisons between these studies of various ethnic groups are, however, not entirely reliable due mainly to the use of varying measurement techniques and datum points.

In an attempt to overcome these problems the dental arches from a number of different human ethnic groups were measured, and the dimensions compared by both univariate and multivariate statistical techniques.

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Materials and Methods

Measurements were made of the dental arches of four major ethnic groups of adult man, viz., Caucasoid (modern British), Mongoloid (North American Indian), Negroid (New Guinean and West African), and Australoid (Australian aboriginal). In addition, the dental arches of Anglo-Saxon (Bidford) and 16-18th century British (Moorfields plague pits) were measured in order to gain insight into possible changes which might have taken place in the British population with the passage of time. Although Goose[7] has shown that there has been a reduction in palate size in modern British populations compared with those of more ancient periods, there are little data concerning the over-all size and shape of the dental arches.

The modern British dental arches were measured from study models derived from alginate base hydrocolloid impressions. They were taken from equal numbers of male and female Caucasoid patients attending for routine dental treatment, living within a twenty-mile radius of Birmingham. The dental arches from the remaining population samples were measured directly from dried skulls. Investigation, however, revealed that there was no statistically significant difference between the dimensions measured on hydrocolloid study models and on dried skulls ($P>0.2$ from analysis of variance). Using the criteria listed by Hrdlicka[11], each sample of dried skulls was assessed to comprise equal numbers of males and females, the sexing being checked by three independent observers.

The criteria for the selection of the dental arches for measurement were:

a) an intact dental arch with a full complement of teeth with the exception of the third molars,

b) a normal anteroposterior relationship between the maxillary and mandibular arches,

c) no marked dental imbrication or irregularity,

d) no marked approximal tooth attrition.

The number of individuals within each population sample is shown in Table 1. In view of these stringent criteria the number of dental arches measured from any one population sample was limited. Nevertheless, they were applied in order to reduce to a minimum the variation within each sample. For instance, preliminary trials showed that if measurements were estimated from tooth sockets, rather than teeth in situ, then the error of the measurement technique increased quite considerably.

Dental arch width

The following dimensions of the maxillary and mandibular dental arches were measured using dial calipers.

The dimensions of dental arch width were measured as the average of the distances between the most buccal and lingual convexities of corresponding teeth on each side of the dental arch in the case of molars and premolars. In the case of the dimensions of arch width between the incisors and canines, the average of the distances between the most mesial and distal surfaces of the corresponding teeth on each side of the dental arch was determined. Thus, the dimensions of maxillary and mandibular arch width measured were: 7-7; 6-6; 5-5; 4-4; 3-3; 2-2; and 1-1.

Dental arch length (direct)

The dimensions of dental arch length (direct) were measured as the minimum distances between the centres of adjacent teeth on the left side of the dental arch. Thus, the dimensions measured were 7-6; 6-5; 5-4; 4-3; 3-2; and 2-1, for both the maxillary and mandibular dental arches.

Dental arch length (oblique)

The dimensions of dental arch length (oblique) were measured between the most mesial aspects of anterior teeth and the most distal aspects of posterior teeth, in each case on the left side of the maxillary and mandibular dental arches. The dimensions measured were 1-3; 1-6; and 3-6.

As a test of accuracy the dimensions of five sets of male and five sets of female study models from the modern British population sample, along with five sets of maxillary and mandibular dental arches from each of the other population samples, were measured five times at daily intervals. The mean error of the measurement technique was of the order of two per cent, and from analysis of variance, the variation within population samples proved statistically insignificant compared with that between the different population samples ($P>0.2$).

Statistical analysis

As an initial assessment the mean arch dimensions for the various population samples were compared by means of 't' tests. In addition, nonparametrical statistical techniques (concordance coefficients) were employed to examine the over-all pattern of the arch dimensions in the various samples. The over-all pattern of contrasts between the dental arches of the different population samples was also examined by principal coordinate analysis. This is a multivariate technique based on the Q-technique of Gower[8]. Such a technique not only permits all the arch dimensions to be grouped together, i.e., considering the arch as a unit rather

Mean Dental Arch Dimensions for various Adult Human Ethnic Groups

	Dimension		Austr. x	Austr. s.d.	N.Guin. x	N.Guin. s.d.	W.Afric. x	W.Afric. s.d.	Mong. x	Mong. s.d.	Moorf. x	Moorf. s.d.	A.Sax. x	A.Sax. s.d.	W.Mid. x	W.Mid. s.d.
MAXILLARY ARCH	Width	7-7	55.4	1.16	52.5	0.82	52.6	0.75	55.3	0.73	53.3	0.42	58.4	0.76	53.1	0.64
		6-6	50.4	1.39	47.6	0.78	47.9	0.85	50.8	0.85	48.9	0.41	55.4	0.67	49.7	0.83
		5-5	43.7	1.00	43.1	0.53	44.1	0.46	45.3	0.49	41.6	0.48	46.2	1.01	44.5	0.52
		4-4	40.8	0.42	38.1	0.65	38.2	0.88	43.6	0.52	35.8	0.41	42.5	1.85	41.4	1.04
		3-3	44.6	0.54	35.4	0.75	34.7	0.79	43.2	0.54	39.0	0.42	35.7	0.74	39.9	0.97
		2-2	18.4	1.15	15.9	0.32	16.6	0.83	13.6	1.08	19.3	0.29	17.4	0.88	21.0	1.16
		1-1	9.8	0.78	10.0	0.49	9.5	0.72	9.2	0.73	8.3	0.19	9.3	0.34	6.3	0.77
	Length	7-7														
		6-6	12.5	0.88	11.8	0.29	12.2	0.52	11.3	0.71	10.7	0.38	10.6	0.38	11.0	0.58
		6-6														
		5-5	9.3	0.41	8.5	0.58	9.1	0.43	9.2	0.49	9.2	0.17	7.4	0.62	8.6	0.61
		5-5														
		4-4	8.5	0.44	6.2	0.51	6.6	0.73	7.7	0.57	6.5	0.22	7.6	0.52	7.5	0.93
		4-4														
		3-3	8.5	0.42	6.7	0.53	7.1	0.47	7.9	0.59	7.3	0.24	6.9	0.44	7.8	0.67
		3-3														
		2-2	5.1	0.45	6.8	0.39	6.8	0.44	6.9	0.37	5.5	0.26	6.6	0.46	5.3	0.44
		2-2														
		1-1	2.8	0.59	2.9	0.39	3.4	0.37	4.0	0.51	2.6	0.24	3.2	0.33	2.9	0.57
		1-6	47.7	0.53	37.8	0.63	38.9	0.53	36.0	0.53	39.5	0.22	45.0	0.47	36.9	0.82
		1-3	18.6	1.12	22.3	0.40	22.7	0.58	18.2	0.56	21.0	0.43	21.9	0.56	17.7	1.16
		3-6	31.0	0.56	32.2	0.44	32.9	0.43	39.7	0.99	28.9	0.38	32.0	0.54	33.3	1.25
MANDIBULAR ARCH	Width	7-7	47.8	0.37	49.1	0.69	48.7	0.83	48.7	0.58	48.8	0.47	48.5	0.54	47.8	0.66
		6-6	46.1	0.47	47.5	0.74	47.0	0.55	48.1	0.95	45.3	0.64	44.6	0.57	45.1	1.88
		5-5	38.7	1.23	36.6	1.17	37.2	0.50	35.3	2.15	36.8	0.91	37.7	1.11	36.6	0.86
		4-4	33.6	0.90	32.8	0.83	33.7	0.70	32.9	0.66	32.8	0.33	31.5	1.82	32.3	0.61
		3-3	22.5	0.85	28.2	0.65	28.4	0.80	22.7	0.59	25.0	0.31	27.2	0.53	26.5	1.18
		2-2	14.4	2.41	17.4	0.47	17.1	0.54	15.2	0.68	14.7	0.52	15.9	0.57	15.0	1.17
		1-1	6.9	1.11	6.2	0.80	5.6	0.65	4.7	0.67	5.1	0.31	5.9	0.49	6.0	0.67
	Length	7-7														
		6-6	9.3	0.41	9.1	0.62	9.5	0.31	9.3	0.38	10.7	0.39	10.6	0.40	8.6	0.58
		6-6														
		5-5	8.7	0.48	8.6	0.38	9.4	0.29	8.9	0.69	8.0	0.52	9.0	0.58	7.0	0.49
		5-5														
		4-4	6.8	0.44	7.4	0.61	7.0	0.52	6.3	0.39	7.2	0.23	7.9	0.55	6.1	0.63
		4-4														
		3-3	7.6	0.76	7.1	0.45	7.2	0.38	7.9	0.53	6.4	0.29	6.1	0.45	6.7	0.76
		3-3														
		2-2	4.0	0.53	4.4	0.33	4.2	0.59	4.9	0.47	4.5	0.30	4.8	0.40	3.7	0.79
		2-2														
		1-1	0.9	0.33	1.2	0.39	1.6	0.38	1.2	0.25	1.2	0.21	0.9	0.47	0.9	0.42
		1-6	38.8	0.57	39.8	0.53	38.4	1.13	39.0	0.47	39.3	0.44	38.7	0.72	38.5	0.29
		1-3	18.1	1.11	17.1	0.72	17.8	0.63	18.8	0.49	17.1	0.37	16.6	1.46	17.5	1.18
		3-6	38.5	0.62	32.0	0.81	32.4	0.71	36.7	1.11	31.5	0.73	34.1	0.82	36.0	1.59
No. in sample			20		20		20		20		20		20		40	

x = mean arch dimension (mms); s.d. = standard deviation.

Austr. = Australian aborigine; N.Guin. = New Guinea; W.Afric. = West Africa; Mong. = Mongoloid; Moorf. = Moorfields; A.Sax. = Anglo-saxon; W.Mid. = West Midlands.

TABLE I

than a series of discrete parameters as in univariate statistical techniques, but also serves to separate maximally the constituent groups. Using this technique, the dimensions of (a) the maxillary and mandibular arches combined and (b) the maxillary arches only were compared. Thus, this analysis served to examine the size and shape of the dental arches from the various population samples.

In order to compare the shapes of the dental arches only, rather than both size and shape, each dental arch dimension was standardized according to the area of (a) the maxillary and (b) the mandibular dental arch. The areas of the dental arches were computed from the area enclosed by the datum points.

Using the standardized arch dimensions, the over-all pattern of contrasts between the dental arches of the different population samples was examined utilizing principal coordinate analysis on (a) the maxillary and mandibular arch dimensions combined and standardized according to both the areas of the maxillary and mandibular arches, (b) the maxillary arch dimensions standardized according to both the areas of the maxillary and mandibular arches, (c) the mandibular arch dimensions standardized according to the areas of both the maxillary and mandibular arches, (d) the maxillary arch dimensions standardized according to the area of the maxillary arch and (e) the mandibular arch dimensions standardized according to the area of the mandibular arch.

Results

Mean arch dimensions

The mean arch dimensions along with their standard deviations are listed in Table 1. The general impression emerged (from univariate statistical techniques, i.e., 't' tests) of there being no consistent trend of the dental arch dimensions from one population sample being greater than those from another. This feature was confirmed from computation of concordance coefficients on ranked mean arch dimensions which were all statistically insignificant ($P>0.2$).

Principal coordinate analysis

In general, a similar pattern of contrasts emerged from examination of the principal coordinates for the first two axes of the maxillary and mandibular arch dimensions combined or considered separately, regardless of whether in fact the actual dimensions (Fig. 1) or standarized dimensions (Fig. 2) were considered. This therefore pointed to the fact that the over-all pattern of contrasts for dental arch size and shape is similar to that for dental arch shape only. Thus, from consideration of the first two canonical axes for either the actual or standardized arch dimensions, the dental arches of Australoids, Mongoloids and modern Caucasoids tended to be clustered together as did those of the two samples of Negroids. The two samples of ancient Caucasoids, i.e., Anglo-Saxon and Moorfields, however, tended to be separated one from another, and also from modern Caucasoids.

The general impression of the separation of the dental arches from the various population samples was confirmed from the generalized distance matrix (D^2).

Discussion

In interpreting the present results, it is necessary to bear in mind certain factors relating to the population samples used. The samples were fairly small and the criteria for selection were very stringent. Inevitably, therefore, the selection of the dental arches was not made on a random basis. The modern British group was selected on the basis of there being a normal anteroposterior

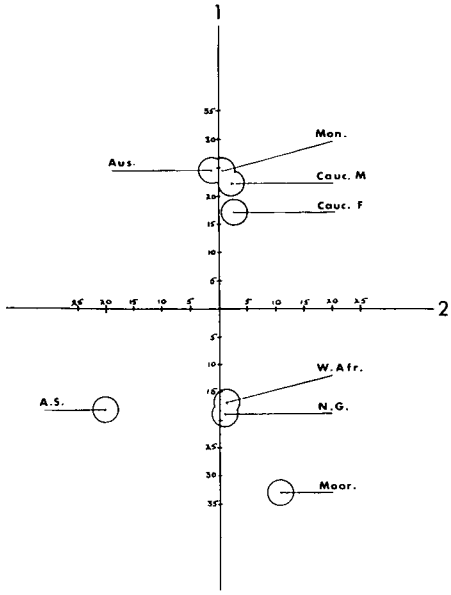

Fig. 1 Principal coordinates and their 90% confidence limits of the first two axes for the maxillary and mandibular arch dimensions combined for various population samples. (Modern Caucasoid sample segregated into male and female, whereas in all the remaining samples, male and female combined).

Aus. = Australoid; Mon. = Mongoloid; Cauc.M. = modern Caucasoid male; Cauc. F. = modern Caucasoid female; W. Afr. = West African; N.G. = New Guinean; A.S. = Anglo-Saxon; and Moor. = Moorfield.

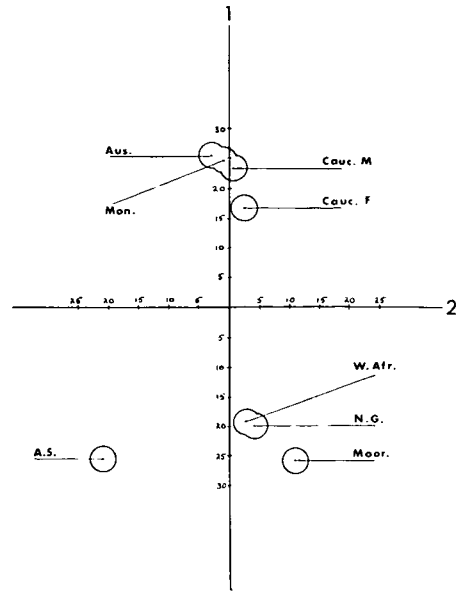

Fig. 2 Principal coordinates and their 90% confidence limits of the first two axes for the maxillary and mandibular arch dimensions combined and standardized according to the areas of the maxillary and mandibular arches for various population samples. (Modern Caucasoid sample segregated into male and female, combined in the remaining samples).

relationship between the dental arches and no crowding of the teeth. It is likely that these criteria would apply to less than fifty per cent of the total British Caucasoid population. Furthermore, although the samples have been chosen to represent various ethnic groups, there are within any major ethnic groups numerous subgroups which may show differences from each other for dental arch measurements[9].

In addition, the definition of different ethnic groups is not always consistent; for example, some anthropologists consider individuals from New Guinea to be Australoids rather than Negroids.

Within these limitations some interesting features arise from the present study. The two Negroid subgroups showed obvious close resemblance to each other and to a lesser extent, there were similarities between the Australoids, Mongoloids and modern Caucasoids for the size and shape of the dental arch. The differences between the modern British on the one hand and the Anglo-Saxon and Moorfields samples on the other were of special interest. It is conceivable that such differences in dental arch size and shape might have resulted from ethnic differences, the modern British having been derived from a much greater mixture of populations than did the Anglo-Saxon and Moorfields population samples. In contrast, such differences may have been the result of environmental factors, e.g., nutrition, function, etc.

In general, the main differences in the dental arch dimensions were in the

measurements of arch length. As tooth dimensions play a greater part in dental arch length than width in the uncrowded arch, variations in tooth dimensions between the various population samples might have been responsible for some of the differences which were found.

The size and shape of the dental arches is governed by several factors including the size and shape of the jaws and the influence of the oral musculature on the position of the teeth. In view of the separation between the various population samples derived from the present results, it is likely that, although environmental factors play a part, genetic factors appear to be important in determining arch size and shape, although this is contrary to the findings of Bowden and Goose[2]. Indeed, arch length was the arch parameter that accounted mainly for the groupings of the population samples. These dimensions essentially reflect variation in mesiodistal tooth diameters. But in view of the stringent criteria for selection, these dimensions were not affected by attrition. Lundstrom[13], however, has illustrated that there is greater variability in dental arch dimensions between fraternal than identical twins.

Thus there are two features to emerge from this study:

a) quite apart from individual variations, there appear to be some basic differences in dental arch size and shape between different population samples;
b) by the use of multivariate rather than univariate statistical techniques, it is possible to compare the complete dental arch rather than individual parameters one with another.

Summary

In order to compare the size and shape of the dental arches in different ethnic groups, measurements were made of adult dental arches from four of the major ethnic groups of man. The groups examined were Caucasoid (modern British), Mongoloid (North American Indian), Negroid (New Guinean and West African) and Australoid (Australian aboriginal). In addition, the dental arches of Anglo-Saxon and 16th-18th century British skulls were measured.

The measurements were subjected to univariate and multivariate statistical analyses using (a) raw dimensions and (b) dimensions of the dental arches standardized according to the areas of the maxillary and mandibular dental arches.

There was no consistent trend of the dental arch dimensions from one population sample being greater than those from another. The multivariate analysis showed that, as far as the form of the dental arches was concerned, the Australoids, Mongoloids and modern Caucasoids tended to be grouped together, as did the two samples of Negroids and the two samples of more ancient Caucasoids. There was considerable separation between each of these three groups, notably between the ancient and the modern Caucasoids.

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References

1. Aitchison, J. Some racial contrasts in teeth and dental arches. *Dent. Mag. and Oral Topics*, 82: 201-205, 1965.
2. Bowden, D. E. and Goose, D. H. The inheritance of palatal arch width in human families. *Arch. Oral Biol.* 13: 1293-1295, 1968.
3. Brown, T., Barrett, M. J. and Darroch, J. N. Craniofacial factors in two ethnic groups. *Growth* 29: 109-123, 1965.
4. Campbell, T. D. Dentition and palate of the Australian aboriginal (Adelaide Univ. K. Sheridan Foundation Publication 1.) Adelaide, 1925.
5. Dockrell, R. B., Clinch, L. M. and Scott, J. H. The face, jaws and teeth

of Arran Island children. *Trans. Europ. Orthodont. Soc.*, pp. 159-220, 1954.

6. Foster, T. D., Hamilton, M. C. and Lavelle, C. L. B. Dentition and dental arch dimensions in British children at the age of 2½-3 years. *Arch. Oral Biol.* 14: 1031-1040, 1969.
7. Goose, D. H. Reduction of palate size in modern populations. *Arch. Oral Biol.* 7: 343-350, 1962.
8. Gower, J. C. A Q-technique for the calculation of canonical variates. *Biometrika* 53: 588-590, 1966.
9. Hiernaux, J. Ethnic differences in growth and development. *Eugen. Quart.* 15: 12-21, 1968.
10. Holcombe, A. E. and Meredith, H. V. Width of the dental arches at the deciduous canines in white children 4 to 8 years of age. *Growth* 20: 159-177, 1966.
11. Hrdlicka, A. *Practical Anthropometry.* Edited by Stewart, T. D. Wistar Institute of Anatomy and Biology, Philadelphia, 1947.
12. Knott, V. B. Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence. *Amer. J. Phys. Anthrop.* 19: 263-284, 1961.
13. Lundstrom, A. An investigation of 202 pairs of twins regarding fundamental factors in the aetiology of malocclusion. *Trans. Europ. Orthodont. Soc.* pp. 161-176, 1948.
14. Moorrees, C. F. A. *The dentition of the growing child.* Cambridge, Harvard University Press, 1959.
15. Moorrees, C. F. A. and Reed, R. B. Biometrics of crowding and spacing of the teeth in the mandible. *Amer. J. Phys. Anthrop.* 12: 77-88, 1954.
16. Moss, M. L. and Chase, P. S. Morphology of Liberian Negro deciduous teeth. *Amer J. Phys. Anthrop.* 25: 261-267, 1967.
17. Seipel, C. M. Variations of tooth position. *Svensk. Tandl. Tidskrift.* 39 Suppl., 1946.
18. Shaw, J. C. M. *The teeth, the bony palate and the mandible in Bantu races of South Africa.* John Bale, Sons and Danielson, London, 1931.