European Journal of Orthodontics 22 (2000) 135–142

Analysis of dental casts of 6–8- and 12-year-old Kenyan children

J. Hassanali* and J. W. Odhiambo**
Departments of *Human Anatomy and **Mathematics, University of Nairobi, Kenya

SUMMARY Dental plaster casts of 97 6–8-year-old and 173 12-year-old Maasai, Kikuyu, and Kalenjin children were studied. The Kikuyu are Bantu, while Maasai and Kalenjin are Nilo-Hamitic subjects. The variables measured were palatal depth (PD) and length (PL); maxillary and mandibular anterior arc circumferences (AC1) and (AC2), respectively; posterior arc circumferences (PC1) and (PC2), inter-canine (CC1), and (CC2); inter-molar (MM1) and (MM2) distances, and mandibular length (ML). The data were analysed using SPSS package.

The mean values of all the variables were generally higher in the males compared with the females and significant sex differences in the means ($P < 0.01$) were found in AC1, PC1, PC2, CC1, CC2, MM1, and MM2 in the 12-year-old subjects. The means of all variables, except PL, ML, PC2, and CC2, increased from 6 to 12 years of age and significant differences in the means for age were found in ML, AC1, PC2, PD, MM1, MM2, and CC1. Mean maxillary inter-molar distance increased with age by 0.17–0.34 mm in the three groups. Mean values of mandibular variables were highest in the Kikuyu, while maxillary variables were highest in the Maasai. The Maasai casts showed a marked decrease in CC2, PC2, AC2, and ML compared with the Kikuyu and Kalenjin. Ethnic and sex differences in the dental arches may be masked by anterior tooth positions that are influenced by the dento-alveolar complex and soft tissues. Corresponding mandibular and maxillary variables were strongly correlated and anterior and posterior arc circumferences were correlated with inter-canine and inter-molar distances. Details of the norms for dental arch dimensions and changes with age may allow for appropriate assessment of dental occlusion and treatment planning for Kenyan children.

Introduction

Human dental arches change in size and shape in relation to age. Many factors such as heredity, bone growth, eruption and inclination of teeth, macro- and micro-environment, external influences, and function affect changes in the size and shape of dental arches (Lavelle *et al.*, 1970).

Individual variations which are genetically determined within populations seem to obscure differences between population groups (Foster, 1990). Several dimensions of dental arches and dental traits can be used to determine how they vary with age between groups, and also how useful the differences are in discriminating amongst human groups (Keiser, 1990). The differences may be biologically meaningful between groups and in micro-evolutionary trends or they may be unimportant compared with the variations within a single group or closely related groups. (Lavelle *et al.*, 1971; Sarhan and Diwan, 1987; Foster, 1990; Younes *et al.*, 1995).

Sexual dimorphism in human odontometrics has been considered using *t*-test univariate and multivariate analysis (Keiser, 1990).

Different ethnic groups show variations in size and shape of dental arches such as prognathic in Negroids and mesognathic in Mongoloids (Lavelle *et al.*, 1971; Smith and Bailit, 1977; Björk *et al.*, 1984; Foster, 1990).

Kenya has a population of approximately 27 million people, mainly Africans of various ethnic groups such as the Kikuyu, Maasai, Luo, Abaluhyia, Kalenjin, and Swahili (Seligman, 1957; Adamson, 1967). Three Kenyan ethnic

groups are included in the present study. The Maasai are pastoralists of Nilo-Hamitic origin who carry out traditional extraction of mandibular deciduous and permanent central incisors (Hassanali and Amwayi, 1993). From 1960, the Maasai also removed the deciduous canine tooth buds in infants resulting in missing deciduous canines in children aged 3–8 years (Hassanali *et al.*, 1995). The Kikuyu are mainly agriculturist of Bantu origin while the Kalenjin are thought to be Nilotic or Nilo-Hamitic, with history of pastoralism.

The aim of present study was to analyse selected dimensions on plaster dental casts of 6–8- and 12-year-old Maasai, Kikuyu, and Kalenjin children to obtain norms for these groups, and to examine differences in dental arch dimensions with age and sex, within groups and between the three groups. The data on the dental arch dimensions for Kenyans would be useful in dental treatment, particularly orthodontics and prosthodontics.

Materials and methods

Dental casts of 97 6–8-year-old and 173 12-year-old Maasai, Kikuyu, and Kalenjin children were used in the study. The children attended rural and peri-urban schools in Kajiado (Maasai), Muranga (Kikuyu), and Baringo (Kalenjin) districts of Kenya. Both parents of each child were from the same ethnic group. The children aged 6–12 years were randomly selected from each of the eight classes in the school.

The dental casts, with the first permanent molar and up to the permanent lateral incisors erupted, were placed in the 6–8-year sample (mixed dentition), and those with one or more second molars erupted were put in the 12-year age sample. In the Maasai, 78 per cent of the children had undergone extraction of mandibular deciduous and permanent central incisors and these teeth were missing in the casts (Hassanali and Amwayi, 1993). In the 6–8-year-old Maasai sample, in the 37 males and 19 females, 15 males and six females had all the deciduous canines present, while these were missing in the mandibular arch (10 females and eight males), maxillary arch (one male) or both arches (three females and 13 males) as a result of removal of the canine tooth bud in infancy (Hassanali *et al.*, 1995).

Table 1 The distribution of the sample by age and sex for the three ethnic groups.

	Maasai		Kikuyu		Kalenjin		
Age	M	F	M	F	M	F	Total
6–8 years	37	19	10	10	10	11	97
12 years	39	26	40	42	11	15	173
Total	76	45	50	52	21	26	270

Dental casts with intact erupted teeth in which centric occlusion could be established, were used for the study.

Table 1 shows the distribution of the sample by age and sex of the three ethnic groups.

Vernier calipers were used for the straight measurements in centimetres to the nearest second decimal place. Palatal depth was measured using a flexible curvature gauge, and a calibrated tape was used to measure the anterior and posterior arc circumference in centimetres to the nearest first decimal place (Figure 1).

The following measurements of dental arch dimensions were made (see Figure 2).

Palatal length (PL) from the centre of palatal incisal papilla to the point on a horizontal line drawn along the distal margins of the first permanent molars.

Palatal depth (PD) perpendicular to the mid-point of a line drawn along the distal margins of the first permanent molars.

Inter-molar distance (MM1-maxillary and MM2-mandibular) was measured from the buccal groove on the occlusal surface along the buccal margin of the first permanent molar to the contralateral tooth.

Inter-canine distance (CC1-maxillary and CC2-mandibular) from the tip of cusp of the canines across the arch.

Anterior arc circumference (AC1-maxillary and AC2-mandibular) from the point of maximum convexity of the canine in the middle third of the buccal surface along the anterior teeth to the similar point on the canine on the opposite side of the arch.

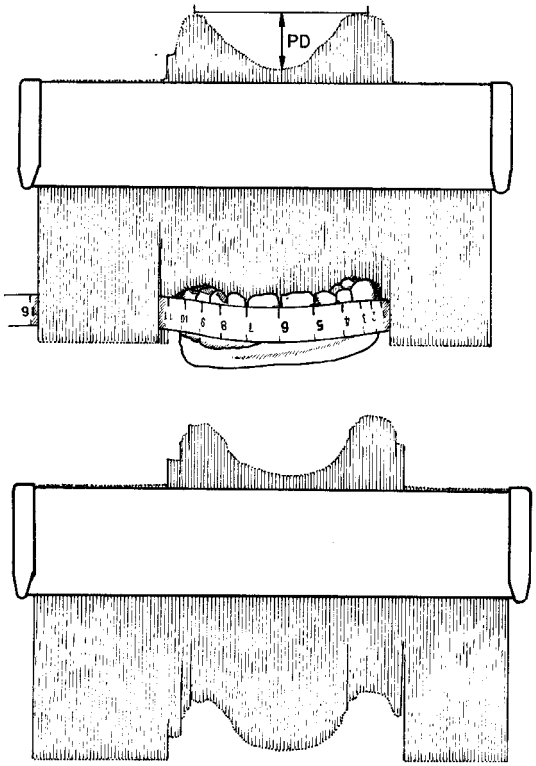

Figure 1 The flexible curvature gauge and calibrated tape used for measuring anterior and posterior arc lengths and palatal depth (PD).

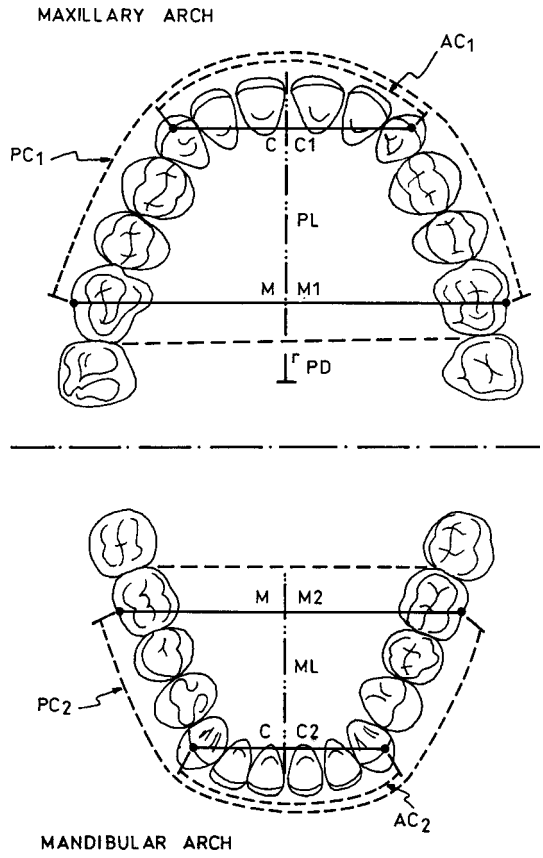

Figure 2 The variables of the dimensions measured in the maxillary and mandibular dental arches. PL, palatal length; PD, palatal depth; inter-molar distance, maxillary MM1 and mandibular MM2; inter-canine distance, maxillary CC1 and mandibular CC2; anterior arc circumference, maxillary AC1 and mandibular AC2; posterior arc circumference, maxillary PC1 and mandibular PC2; ML, mandibular length.

Posterior arc circumference (PC1-maxillary and PC2-mandibular) from the maximum convexity on the buccal groove of the first permanent molar buccally along the middle third of the teeth in the arch to the same point on the opposite side.
Mandibular length (ML) from the centre of the lingual incisor papilla between the central incisors to the point on a horizontal line drawn along the distal margins of the first permanent molars. In the Maasai with missing central incisors, the mid-point of the ridge was used instead of the papilla.

All the measurements were checked for inter- and intra-observer errors using a pairwise *t*-test (n = 12). The test indicated significant inter-observer differences in (MM1) and (CC2) only and intra-observer error in CC1 only ($P < 0.05$).

The analysis was carried out using SPSS for descriptive statistics, *t*-test for differences between means and bi-variate correlations of variables. This was undertaken within groups for sex and age, and also between the three ethnic groups. A two-sample *t*-test was used to determine the significance in means between the sex and age in each group.

Results

Tables 2 and 3 show the mean, SD, and SE (cm) of the variables in males and females and all combined in the 6–8- and 12-year-old Kikuyu, Maasai, and Kalenjin children, respectively.

Table 2 The mean (X), SD, and SE (cm) of the variables in males and females, separately and combined in the 6–8-year-old Kikuyu, Maasai, and Kalenjin children.

		Kikuyu			Maasai			Kalenjin			All combined		
Variable	Sex	X	SD	SE	X	SD	SE	X	SD	SE	X	SD	SE
AC1	M	4.24	0.31	0.10	4.15	0.38	0.08	4.02	0.43	0.14	4.12	0.36	0.04
	F	4.12	0.44	0.14	4.01	0.28	0.07	4.21	0.33	0.10			
AC2	M	3.29	0.29	0.10	2.94	0.27	0.07	2.97	0.19	0.06	3.07	0.28	0.04
	F	3.18	0.25	0.08	2.98	0.25	0.10	3.12	0.28	0.09			
PC1	M	9.61	0.51	0.10	9.47	0.52	0.09	9.70	0.60	0.20	9.47	0.49	0.05
	F	9.37	0.49	0.11	9.34	0.37	0.09	9.49	0.44	0.13			
PC2	M	9.01	0.60	0.20	8.63	0.49	0.08	8.83	0.26	0.08	8.62	0.48	0.05
	F	8.48	0.30	0.15	8.40	0.45	0.10	8.54	0.46	0.14			
CC1	M	3.52	0.20	0.06	3.37	0.26	0.06	3.37	0.30	0.09	3.39	0.24	0.03
	F	3.38	0.19	0.05	3.30	0.18	0.05	3.45	0.24	0.07			
CC2	M	2.88	0.28	0.09	2.64	0.24	0.07	2.52	0.20	0.06	2.66	0.24	0.03
	F	2.67	0.16	0.08	2.64	0.24	0.10	2.62	0.19	0.06			
MM1	M	5.44	0.25	0.09	5.29	0.27	0.05	5.49	0.25	0.09	5.31	0.25	0.03
	F	5.29	0.19	0.06	5.14	0.20	0.05	5.39	0.16	0.05			
MM2	M	4.77	0.24	0.08	4.69	0.27	0.05	4.89	0.73	0.11	4.70	0.24	0.02
	F	4.66	0.17	0.06	4.57	0.18	0.04	4.89	0.73	0.11			
PD	M	1.24	0.17	0.06	1.35	0.15	0.03	1.20	0.12	0.04	1.27	0.17	0.02
	F	1.29	0.16	0.05	1.45	0.16	0.07	1.17	0.18	0.06			
PL	M	3.77	0.23	0.08	3.75	0.25	0.04	3.81	0.24	0.08	3.73	0.22	0.02
	F	3.66	0.22	0.06	3.70	0.15	0.04	3.71	0.23	0.07			
ML	M	3.60	0.21	0.08	3.45	0.25	0.05	3.39	0.10	0.03	3.40	0.22	0.02
	F	3.31	0.12	0.04	3.33	0.17	0.04	3.34	0.22	0.07			

Sex differences

Mean values of all variables were higher in the males compared with the females in all three ethnic groups except for AC1, AC2 and CC1, CC2 in Kalenjins which were a little higher in the 6–8-year-old sample.

There was no significant sex difference in the means 6–8-year-old sample, while significant sex differences ($P < 0.01$) were found in the AC1 (Maasai, Kikuyu); PC1 in all three groups; PC2, CC2 (Kikuyu); CC1, MM2 (Kikuyu, Kalenjin), and MM1 (Maasai, Kalenjin) in the 12-year-old as shown by the asterisk in Table 3.

Age differences

The means of all variables increased from 6–8 to 12 years, except for PC2, PL, and ML, which decreased in all three groups, and CC2 in Kikuyu and Maasai. Significant differences in the mean values for age ($P < 0.01$) were found in the three groups for ML, AC1, PC2, and PD; MM1, MM2 in the Maasai, and CC1 in the Maasai and Kikuyu.

The maxillary inter-molar distance increased more than the mandibular with age. The increase in the maxillary inter-molar distance with age in the Kikuyu, Maasai, and Kalenjin was 0.17, 0.34, and 0.27 cm, respectively. The inter-canine distance in the maxilla increased with age by approximately 0.13–0.3 cm in the three groups, and decreased in the mandible by 0.03–0.17 cm in the Kikuyu and Maasai.

Ethnic differences

In the 6–8-year-old sample, the highest means were in the Kikuyu for AC1, AC2, CC1, and CC2; in Maasai for PC2, PD, PL, and ML; and in the Kalenjin for PC1, MM1, and MM2.

In the 6–8-year-old Maasai sample, significant differences in the means only for PC1 and PC2

Table 3 The mean (X), SD, and SE (cm) of the variables in males and females and all combined in the 12-year-old Kikuyu, Maasai and Kalenjin Children.

		Kikuyu			Maasai			Kalenjin			All combined		
Variable	Sex	X	SD	SE	X	SD	SE	X	SD	SE	X	SD	SE
AC1	M	4.58*	0.31	0.05	4.77*	0.35	0.06	4.60*	0.21	0.07	4.57	0.33	0.03
	F	4.42*	0.27	0.04	4.53*	0.29	0.06	4.40*	0.32	0.08			
AC2	M	3.32	0.22	0.03	2.94	0.37	0.06	3.29	0.25	0.08	3.14	0.32	0.03
	F	3.24	0.18	0.03	2.91	0.35	0.07	3.19	0.24	0.07			
PC1	M	9.79	0.56	0.09	9.84	0.46	0.07	9.73	0.39	0.12	9.64	0.52	0.04
	F	9.47*	0.49	0.08	9.54*	0.42	0.08	9.27*	0.49	0.13			
PC2	M	8.53	0.46	0.07	8.07	0.43	0.07	8.41	0.43	0.13	8.22	0.47	0.04
	F	8.19*	0.38	0.06	8.08	0.48	0.10	7.98	0.48	0.13			
CC1	M	3.65	0.22	0.04	3.69	0.24	0.04	3.70	0.18	0.05	3.60	0.24	0.02
	F	3.52*	0.21	0.03	3.55	0.23	0.05	3.46*	0.24	0.06			
CC2	M	2.81	0.21	0.03	2.49	0.37	0.06	2.64	0.34	0.10	2.63	0.29	0.02
	F	2.68*	0.19	0.03	2.49	0.30	0.06	2.63	0.21	0.06			
MM1	M	5.61	0.27	0.04	5.63	0.22	0.03	5.74	0.19	0.06	5.55	0.25	0.02
	F	5.49	0.23	0.04	5.42*	0.26	0.05	5.41*	0.22	0.06			
MM2	M	4.93	0.26	0.04	4.88	0.22	0.03	4.93	0.24	0.07	4.83	0.25	0.02
	F	4.78	0.23	0.04	4.75	0.26	0.05	4.67	0.24	0.07			
PD	M	1.62	0.27	0.04	1.66	0.21	0.04	1.55	0.25	0.08	1.59	0.22	0.05
	F	1.55	0.18	0.03	1.55	0.20	0.04	1.59	0.24	0.06			
PL	M	3.70	0.29	0.05	3.77	0.28	0.05	3.68	0.21	0.06	3.67	0.25	0.02
	F	3.60	0.22	0.04	3.62	0.20	0.04	3.60	0.22	0.06			
ML	M	3.24	0.23	0.04	3.10	0.40	0.07	3.21	0.23	0.07	3.15	0.29	0.02
	F	3.14	0.26	0.04	3.07	0.26	0.05	3.10	0.24	0.06			

* Significant sex difference ($P \leq 0.01$).

were found between the casts of those with all four deciduous canines present and the total sample including those with missing canines.

In the 12-year-old children, MM1 was similar in all three groups, while mean values of other maxillary variables were highest in the Maasai. There was no significant difference ($P > 0.01$) in the means for the maxillary arch dimensions.

In the 12-year-old groups, the means of the mandibular variables were highest in the Kikuyu, while those for CC2, AC2, and ML in the Maasai were significantly ($P < 0.01$) lower than the Kikuyu and Kalenjin.

Bi-variate correlations for 12-year-old Maasai and Kikuyu

The corresponding mandibular and maxillary variables were significantly correlated ($P < 0.01$), indicating that there was a fairly strong relationship ($0.4 < r < 0.7$) between the variables.

Palatal length and depth showed weak correlation ($r < 0.3$) in the Kikuyu and Maasai which was not significant ($P > 0.01$)

Palatal and mandibular lengths were strongly correlated ($r > 0.6$) in the Kikuyu while in the Maasai, the correlation ($r < 0.3$) was weak and not significant ($P > 0.01$).

Anterior and posterior arc circumferences were strongly correlated to inter-canine ($r > 0.7$), and inter-molar distances ($0.4 < r < 0.7$) in the Maasai and Kikuyu.

The posterior arc circumference showed a strong significant ($P < 0.01$) correlation to the palatal and mandibular lengths ($r > 0.7$).

Discussion

The means of selected variables in the dental casts of the three ethnic groups were generally higher in males than in females. Some means showed significant sex difference in the 12-year-old

subjects as has also been found for Egyptians and British (Sarhan and Diwan, 1987) and Cubans and Namibians (Ortega and Aguila, 1986).

The size and shape of the dental arches changed when comparing the 6–8-year-olds with mixed dentition to 12-year-olds in the three groups. It has been shown that the size and shape of the dental arches changes from birth to 25 years (Silman, 1964) with major changes occurring from 5 to 7 years and 11 to 13 years during the period of permanent tooth eruption (Woods, 1948; Lavelle *et al.*, 1970).

Tooth eruption has a marked effect on the form of the dental arches, the shape determined by the direction of alveolar bone growth and the size of arch by the size and alignment of the teeth (Silman, 1964; Lavelle *et al.*, 1970; Foster, 1990).

The palatal and mandibular lengths and mandibular posterior arc circumference were found to decrease with age. The eruption sequence of teeth, especially in the premolar segment, is an important factor in the decrease in posterior arch parameters during growth of the mandible (Ash, 1993). However, the anterior and posterior arc circumferences are also dependent on the growth of the dento-alveolar complex, and degree of overbite and overjet (Björk *et al.*, 1984).

The maxilla and mandible grow in the shape of a 'V' with an increase in the inter-molar and inter-canine distances. The maxillary inter-molar distance increases more than the mandibular inter-molar with age (Woods, 1948). The increase with age in the maxillary inter-molar distance in the Maasai and Kalenjin (0.27–0.34 cm) was more than that in the Kikuyu (0.17 cm). Björk *et al.* (1984) found that the difference in the inter-molar increase was much greater in the Australian Aboriginal (0.7 cm) than in Danes (0.31 cm).

The mandibular variables were highest in the Kikuyu and the maxillary were highest in the Maasai. The mandibular dimensions in the Maasai casts were markedly reduced compared with the Kikuyu and Kalenjin as result of removal of the mandibular central incisors and deciduous canine tooth buds in children (Hassanali *et al.*, 1995). The mandibular inter-molar distance in the Maasai was not affected and this may be due to the position of the tongue as found previously (Hassanali and Amwayi, 1993).

Mean values of some similar dimensions measured in the 12-year-old Maasai and Kikuyu dental casts in the previous study (Hassanali and Amwayi, 1993) vary from those in the present study. This may be due to the difference in the method of measurement.

There was no distinctive ethnic difference in the arch size and shape between the three groups. The Kikuyu, who are Bantu, have a broad and wide palate in keeping with their brachiocephalic faces. By comparison, the Maasai and Kalenjin have dolichocephalic faces (Seligman, 1957; Hassanali and Mwaniki, 1984). Ethnic and age differences in the prevalence, and size of the overbite and overjet in Kenyans have been shown, although masked by dento-alveolar growth and soft tissue influences (Hassanali and Pokhariyal, 1993).

The means for inter-canine and inter-molar distances in the present study were slightly higher than those for Egyptians but less than for the British (Sarhan and Diwan, 1987). Ortega and Aguila (1986) found that the inter-molar distance was greater in the Negroid compared with the Europoid.

Analysis of dental arches of Australasians, Mongoloids, Caucasians, and Negroids show considerable discrimination between arches of the Negroids and Caucasians, and Mongoloids (Lavelle *et al.*, 1971). Comparative studies of Swedes, Danes, Bantu, Nigerians, Greeks, Australians, Americans, and others have also shown that ethnic differences in facial traits do exist, and an awareness of dento-facial pattern of each group will ensure more appropriate dental treatment (Björk *et al.*, 1984; Awofula, 1986; Argyropolous and Sassuni, 1989). Analysis of dental casts in Melanesians from 12 to 68 years of age have emphasized that quantitative evaluation of occlusal variables may reveal differences within populations which are not detected when simple malocclusion frequencies are reported (Smith and Bailit, 1977).

The corresponding maxillary and mandibular variables, as well as arc circumference and inter-arch distance showed a strong correlation as eruption of teeth and development of occlusion

is associated with the development of oral motor function (Ash, 1993).

Patterns of growth of the jaws and development of the occlusion that vary between individuals, as well as population groups may have a bearing on the need, type, and timing of orthodontic treatment. The form and size of the dental arch may start to change earlier in Africans than Caucasians, as permanent teeth start to erupt by 4 years in Africans (Hassanali and Odhiambo, 1981; Blankenstein *et al.*, 1990). Presently, treatment is prescribed on dental status without knowledge of the growth pattern (Foster, 1990).

Studies of malocclusions in Kenyan children need to consider norms for Kenyans, and aspects of how size and shape of the dental arches change with age as these may help in planning appropriate orthodontic treatment (Ng'ang'a *et al.*, 1996).

Conclusions

Analysis of the selected biometric dimensions of the dental casts of children of three Kenyan ethnic groups show changes in the size and shape of the dental arch with age. The means of the variables in the males were higher than the females and significant sex differences were observed in the maxillary arc circumferences, and inter-canine and inter-molar distances in the 12-year-old sample. The maxillary inter-molar distance increased with age, while palatal and mandibular lengths and mandibular arc circumference decreased. Ethnic differences in some mandibular and maxillary variables were observed between the Maasai and Kikuyu. The Kenyans had a broad and wide arch similar to the Negroid form. The corresponding maxillary and mandibular variables were strongly correlated, while arc circumferences were correlated to inter-arc distances in both arches.

Address for correspondence

Professor Jameela Hassanali
Department of Human Anatomy
University of Nairobi
PO Box 30197
Nairobi
Kenya

Acknowledgements

We wish to thank Ms M. Muasya for carrying out the measurements, Mr C. N. Kamwaro for the figures, and the Deans' Committee for the research grant.

References

Adamson J 1967 The people of Kenya. Collins, London

Ash M M 1993 Wheeler's dental anatomy, physiology and occlusion, 7th edn. W B Saunders, Philadelphia

Argyropolous E, Sassouni V 1989 Comparison of the dentofacial patterns for native Greek and American-Caucasian adolescents. American Journal of Orthodontics and Dentofacial Orthopedics 95: 238–249

Awofula A O 1986 A cephalometric appraisal of the Negro bimaxillary proclination. Odonto Stomatology Tropical 9: 121–128

Björk A, Brown T, Skieller V 1984 Comparison of craniofacial growth in Australian Aboriginal and Danes, illustrated by longitudinal cephalometric analysis. European Journal of Orthodontics 6: 1–14

Blankenstein R, Cleaton-Jones K, Luk K, Fatti L 1990 The onset of eruption of the permanent dentition amongst South African black children. Archives of Oral Biology 35: 225–228

Foster T D 1990 A textbook of orthodontics, 3rd edn. Blackwell Scientific Publications, London

Hassanali J, Amwayi P 1993 Biometric analysis of the dental casts of Maasai following traditional extraction of mandibular permanent central incisors and of Kikuyu children. European Journal of Orthodontics 15: 513–518

Hassanali J, Mwaniki D 1984 Palatal analysis and osteology of the hard palate of the Kenyan African skulls. Anatomical Record 209: 273–280

Hassanali J, Odhiambo J W 1981 Ages of eruption of permanent teeth in Kenyan African and Asian children. Annals of Human Biology 8: 425–434

Hassanali J, Pokhariyal G P 1993 Anterior tooth relations in Kenyan Africans. Archives of Oral Biology 38: 337–342

Hassanali J, Amwayi P, Muriithi A 1995 Removal of deciduous canine tooth buds amongst the Maasai children. East African Medical Journal 72: 207–209

Keiser J 1990 Human adult odontometrics. Cambridge University Press, Cambridge

Lavelle C L, Flinn R M, Foster T D, Hamilton M 1970 An analysis into age changes of human dental arch by a multivariate technique. American Journal of Physical Anthropology 33: 403–412

Lavelle C , Foster T, Flinn R 1971 Dental arches in various ethnic groups. Angle Orthodontist 41: 293–299

Ng'ang'a P M, Ohito F, Øgaard B, Valderhaug J 1996 The prevalence of malocclusion in 13- to 15-year-old children in Nairobi, Kenya. Acta Odontologica Scandinavica 54: 126–130

Ortega G, Aguila F 1986 Analysis of transverse maxillary diameter, using Mayoral's method in Cuban and Namibian young people with normal occlusion. Anatomocal Anzeiger 161: 53–60

Sarhan D A, Diwan R R 1987 Maxillary arch dimensions in Egyptians and British children. Tropical Dental Journal 2: 101–106

Seligman C G 1957 Races of Africa. Oxford University Press, Oxford

Silman H 1964 Dimensional changes of the dental arches: longitudinal study from birth to 25 years. American Journal of Orthodontics 50: 824–842

Smith R J, Bailit H W 1977 Variation in the dental occlusion and arches among the Melanesians of Bougainville Island, Papua New Guinea. American Journal of Physical Anthropology 47: 195–208

Woods G A 1948 Changes in width dimensions between certain teeth and facial points during human growth. Thesis, University of Illinois

Younes S, El Angbawi M F, Al Dosari A M 1995 A comparative study of palatal height in a Saudi and Egyptian population. Journal of Oral Rehabilitation 22: 391–395