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Palatal rugae

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INTRODUCTION

The palatal rugae, the generally transverse ridges situated in the anterior part of the palatine mucosa, are widely present in mammals, but their biological significance is little understood. In the human embryo they are relatively prominent, occupying much of the length of the palatal shelves at the time of their elevation (Gegenbaur, 1878; Waterman & Meller, 1974), but become less prominent during fetal growth and, from the newborn stage onwards, are confined to the anterior part of the secondary palate. From studies on several large series of children and adults a reduction in mean palatal ridge number with age has been established (Lysell, 1955; Yamazaki, 1962*a*, *b*; Reuer, 1973). However, such changes in the mean ridge counts are, at most, moderate in adolescence but increase markedly from the age group of 35 to 40 years onwards (Yamazaki, 1962*a*, *b*). The pattern of ridges may be simple or of varying degrees of complexity. Extreme finger sucking in infancy may bring about changes in the pattern (Hausser, 1950, 1951), and orthodontic treatment which causes the movement of premolars or molars in a sagittal direction causes displacement of the rugae, particularly of their lateral parts. Studies of their inheritance show varying results. Twin and family studies by Ritter (1943), Nilles (1950, 1952), Klenke (1951) and Lysell (1955) suggest an appreciable hereditary component, but this varies in extent in the different investigations and also from feature to feature.

In an endeavour to understand their biological significance, a study has been made of the variation in palatal rugae between and within two genetically and environmentally distinct populations, Greeks of southern Europe and Swazi, a Bantu population from southern Africa. Such a comparison was made possible by the recent development of a semi-quantitative method of analysis by Szilvassy & Hauser (1983), based on an earlier method of Reuer (1973). It distinguishes between main and secondary ridges, counts them and scores them for strength, direction, regularity and pattern complexity (presence and strength of forking and presence of islands). At the same time, the midline structures are also included, the palatal raphe is scored for the presence, strength and location of forking, and the papilla incisiva is scored for size and shape.

MATERIALS AND METHODS

The first sample was from Swaziland and consisted of Swazi from Mbabane and surrounding villages. There were 47 males and 70 females, ranging in age from 12 to 60. The youngest subjects all had the second molar teeth fully erupted, and all the older adults still retained at least 12 maxillary teeth. Impressions of the anterior palate were taken using a self-hardening plastic, Blendiscon. For each subject a small amount

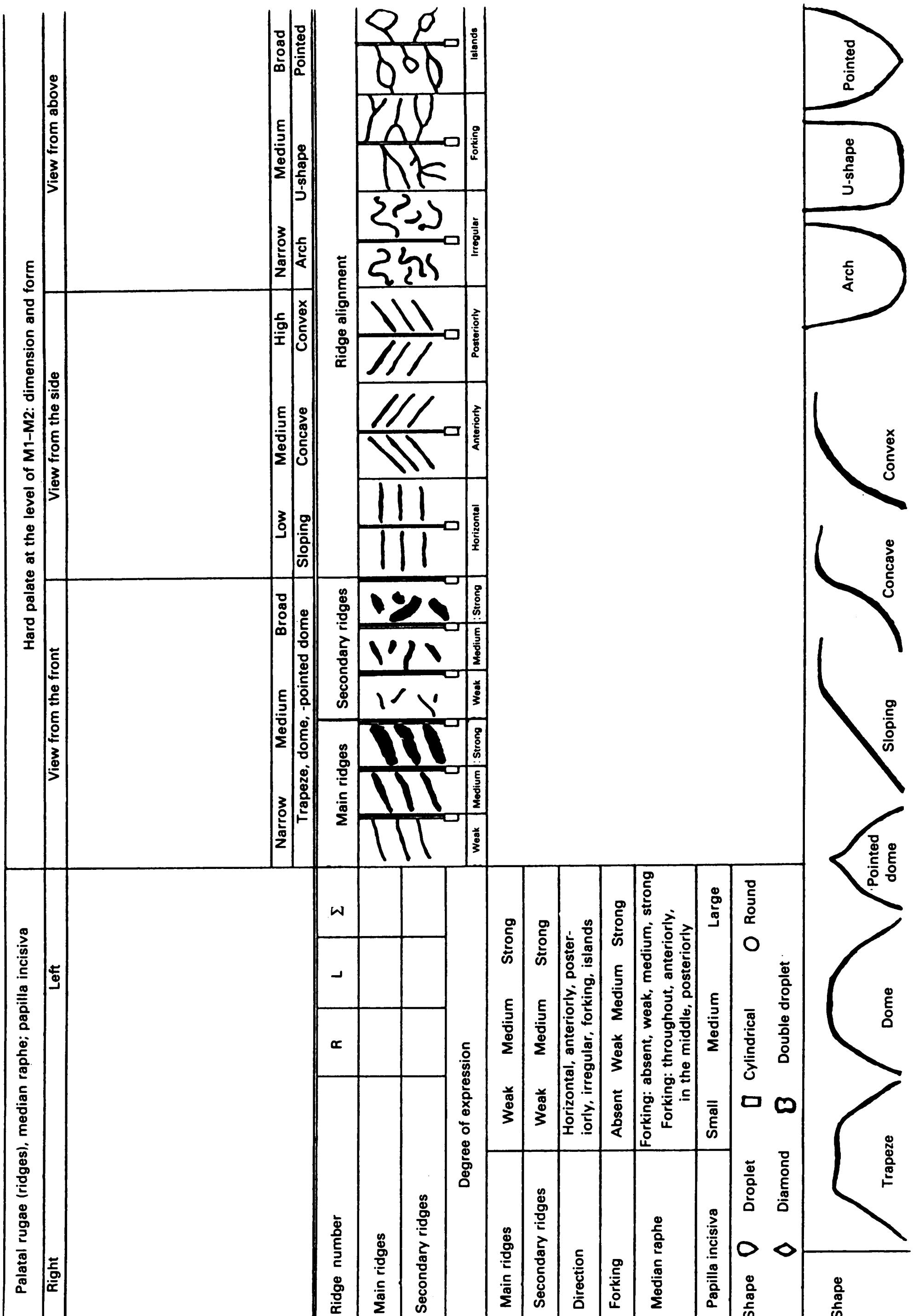

Fig. 1. Protocol for the scoring procedure.

Table 1. *Number of subjects by ridge number*

No. of ridges	Main								Secondary							
	Right				Left				Right				Left			
	Swazi		Greek		Swazi		Greek		Swazi		Greek		Swazi		Greek	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
0	—	—	7	2·6	—	—	6	2·2	56	47·9	106	39·0	53	45·3	76	27·9
1	—	—	19	7·0	—	—	15	5·5	44	37·6	65	23·9	41	35·0	59	21·7
2	6	5·1	30	11·0	2	1·7	26	9·6	13	11·1	40	14·7	19	16·2	66	24·3
3	24	20·5	59	21·7	20	17·1	69	25·4	4	3·4	35	12·5	4	3·4	36	13·2
4	43	36·8	84	30·9	31	26·5	76	27·9	—	—	15	5·5	—	—	20	7·4
5	31	26·5	46	16·9	38	32·5	45	16·5	—	—	5	1·8	—	—	8	2·9
6	8	6·8	18	6·6	19	16·2	25	9·2	—	—	4	1·5	—	—	5	1·8
7	5	4·3	7	2·6	6	5·1	6	2·2	—	—	1	0·4	—	—	2	0·7
8	—	—	1	0·4	1	0·9	3	1·1	—	—	1	0·4	—	—	—	—
9+	—	—	1	0·4	—	—	1	0·4	—	—	—	0·4	—	—	—	—
	117		272													
χ^2	17·2				27·5				25·5				36·8			
D.F.	5				4				3				3			

of the substance was mixed with the activator, shaped to fit the mouth roof, inserted into the mouth, pressed gently against the palate for a minute or so until it hardened, and then removed, rinsed, dried and labelled. The impressions were subsequently photographed, at standard distance together with scales, and the prints analysed (Hauser & Roberts, 1986).

The second sample consisted of Greeks from the Thessalonica area. There were 272 subjects, 114 males, 108 females, and 50 for whom unfortunately the sex was not recorded. They were all prepubertal children, of differing social backgrounds, but all attending primary schools. The same procedure of obtaining the impression was followed.

All the photographs were analysed by the same author, using the technique described in detail by Szilvassy & Hauser (1983). Figure 1 illustrates the categories used.

RESULTS

Interpopulation variation

The distribution of the number of main ridges in Swazi is significantly different from that among the Greeks, a greater proportion of Swazi having higher main ridge numbers (Table 1). The contrary holds for the secondary ridges, for the majority of Swazi have very few, and none more than three, whereas in the Greeks there are individuals with 7, 8 or 9 secondary ridges. In the Swazi, then, there are more main and fewer secondary, and in the Greek fewer main and more secondary. The differences between the two populations are highly significant on each side, for both main and secondary ridges.

The mean numbers within sexes (Table 2) show the same pattern, with significant differences between the two populations in all except the right secondary ridges in males, and the right and combined sides main ridges in females. The two populations differ, however, in their sex differences: in the Swazi the sexes are significantly different in the number of main but not secondary ridges, while in the Greeks the sex differences occur in the secondary but not the main ridges. These ridge numbers are the only

Table 2. *Number of rugae*

	Males		Females		Differences between sexes	
	m	S.D.	m	S.D.	t	P
Swazi	(n = 47)		(n = 70)			
Main ridges						
R	4·53	1·18	4·01	1·07	2·46	0·015
L	4·96	1·27	4·41	1·10	2·47	0·015
R+L	9·49	2·34	8·43	1·95	2·66	0·009
Secondary						
R	0·79	0·88	0·64	0·74	NS	
L	0·77	0·87	0·80	0·83	NS	
R+L	1·55	1·56	1·44	1·44	NS	
Greek	(n = 114)		(n = 108)			
Main ridges						
R	3·70	1·38	3·87	1·62	NS	
L	3·92	1·30	3·94	1·65	NS	
R+L	7·62	2·38	7·81	2·99	NS	
Secondary						
R	1·12	1·35	1·53	1·62	2·03	0·043
L	1·47	1·48	1·98	1·59	2·47	0·014
R+L	2·60	2·48	3·51	2·94	2·50	0·013
Differences between populations	t	P	t	P		
Main ridges						
R	3·61	< 0·001	NS			
L	4·64	< 0·001	2·14	0·033		
R+L	4·54	< 0·001	NS			
Secondary						
R	NS		4·30	< 0·001		
L	3·07	0·003	5·71	< 0·001		
R+L	2·67	0·008	5·45	< 0·001		

character in which a sex difference appears, so for the remainder of the analysis the sexes are combined.

Within each population there is significant symmetry between right and left sides (Figs. 2*b*, *c*, 3*a*, *b*). The correlation coefficients between right and left for number of main ridges is +0·73 amongst the Swazi and +0·64 amongst the Greeks. For the secondary ridges, the correlations are respectively +0·62 and +0·63. There is a slight negative association between secondary and main ridges, the correlation coefficients among the Swazi being −0·13 for the right and −0·27 for the left, and among the Greeks −0·42 and −0·36 respectively. The presence of many main ridges thus seems to imply fewer secondary, both within populations and between them.

The populations appear to differ in the strength of ridges. Whereas in the Greek, weak or absent main ridges occur in some 9 % and secondary ridges in 30 %, no weak or absent main ridges are seen in Swazi (Table 3), and the distributions differ significantly in the two populations (χ^2 main ridges 61·8, 1 D.F., secondary 14·2, 2 D.F.).

The populations do not differ in the direction of the main ridges (Table 4), nor in the proportions with regular or irregular ridge patterns (Table 5). However, they do differ in ridge complexity. Whereas forking is universally present in the African sample, it is absent in 9 % of Greeks; islands are present in a larger proportion of Swazi palates; and greater strength of forking is more common in Swazi. Differences between the two populations in these three measures of complexity are highly

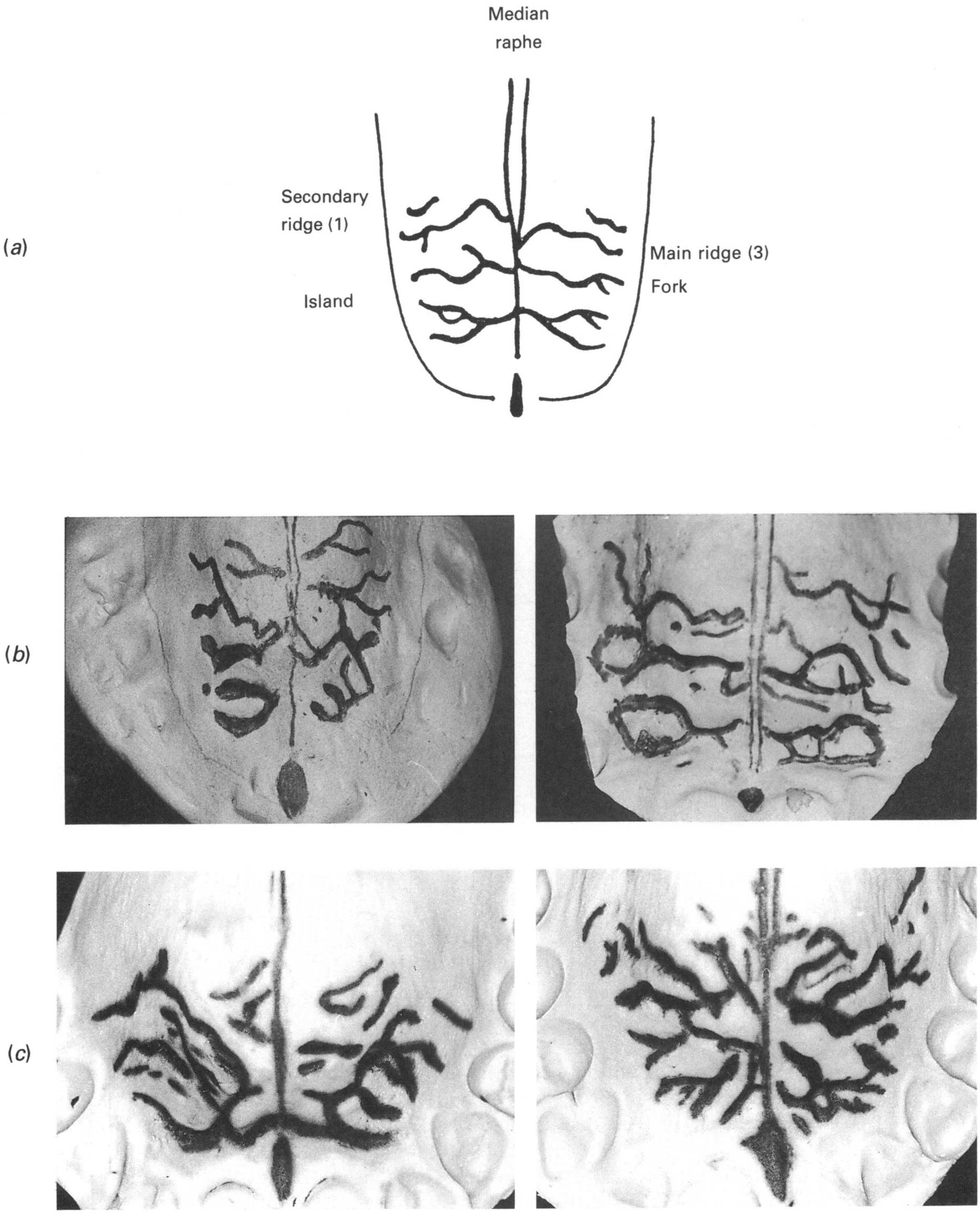

Fig. 2(*a–c*). (*a*) Definitions. (*b*) A pair of Greek palates seen from above. (*c*) A pair of Swazi palates seen from above. (*b*, *c*) on same scale, approx. $\times 1\frac{1}{2}$.

Table 3. *Strength of ridges*

	Main				Secondary			
	Swazi		Greek		Swazi		Greek	
	n	%	*n*	%	*n*	%	*n*	%
Weak or absent	—	—	25	9·2	51	43·6	81	29·8
Medium	14	12·0	126	46·3	48	41·0	141	51·8
Strong	103	88·0	121	44·5	18	15·4	50	18·4
χ^2	61·75				14·2			

Table 4. *Direction of main ridges*

	Swazi		Greek	
	n	%	*n*	%
Horizontal	37	31·6	78	28·7
Towards front	58	49·6	128	47·1
Towards rear	1	0·9	4	1·5
Nondirectional	21	17·9	62	22·8

Table 5. *Complexity of main ridges*

	Swazi		Greek		
	n	%	*n*	%	
Ridges					
Regular	69	59·0	171	62·9	NS
Irregular	48	41·0	101	37·1	
Forking					
Present	117	100	247	90·8	*P* 0·00014
Absent	—	—	25	9·2	
Islands					
Present	71	60·7	115	42·3	*P* 0·0006
Absent	46	39·3	157	57·7	
Forking					
Weak or absent	21	18·0	137	50·3	
Medium	57	48·7	98	36·9	χ^2_2 40·8
Strong	39	33·3	37	13·6	

significant. In the Swazi not only are there more main ridges, but they also tend to be stronger and organised in more complex patterns, while secondary ridges tend to be fewer and weaker. In the Greeks, there seems to be more emphasis on secondary ridges.

The midline structures (Table 6) show similar significant differences between the two populations. The palatal raphe tends to be more strongly forked in the Swazi, in more subjects forking is total, and fewer show no forking. A large papilla incisiva characterises the majority of Swazi (Fig. 3*b*) none of whom has the small papillae that occur in a quarter of the Greeks. The variation in shape among the Greeks appears rather less even, and the modal shape is different in the two populations.

Table 6. *Midline structures*

	Swazi		Greek		
	n	%	*n*	%	
		Raphe			
Forking					
Raphe absent	0	—	13	4·8	
Not forked	11	9·4	47	17·3	
Narrow	25	21·4	72	26·5	χ^2_3 9·85
Medium	47	40·2	92	33·8	
Wide	34	29·1	48	17·6	
	117		272		
Position of fork					
Total	56	47·9	101	36·8	
Front	2	1·7	10	3·7	
Middle	—	—	20	7·4	χ^2_2 9·58
Rear	48	41·0	81	29·8	
Raphe absent or not forked	11	9·4	60	22·1	
		Papilla incisiva			
Size					
Small	—	—	68	25·7	
Medium	18	15·4	136	50·0	χ^2_1 119·5
Large	99	84·6	66	24·3	
			270		
Shape					
Droplet	27	23·1	150	55·1	
Cylindrical	26	22·2	78	28·7	
Round	4	3·4	2	·7	χ^2 63·8
Diamond	47	40·2	27	9·9	
Double drop	13	11·1	13	4·8	

As regards palate size, the well-known difference in palate breadth between Africans and Europeans is clearly brought out in Table 7, for the distribution of size assessments in the two populations differs significantly no matter whether scored from the anterior, lateral, or superior view. Broad palates are almost universal amongst the Swazi (Fig. 3*b*), but occur in only a minority of Greeks (Fig. 3*a*). In palate shape the lateral cross-section (anterior view) shows little difference, but from the lateral view the Swazi show significantly fewer simple sloping sagittal cross-sections and more that are concave or convex (Fig. 3*c*, *d*). The shape of the dental arcade (vertical view), moreover, shows different distributions in the two populations, more Greeks having a pointed or a U-shape (Fig. 2*b*), whereas Swazi show exclusively an arch form (Fig. 2*c*).

Intra-population variation

(a) Greek

The strength of main and secondary ridges are significantly associated ($\chi^2 = 50{\cdot}9$, 2 D.F.) so that weaker secondary ridges tend to be associated with weak main ridges. There is a significant association of directionality with main ridge strength ($\chi^2 = 17{\cdot}1$, 2 D.F.) so that absence of clear alignment is associated with weak main ridges, and clear directionality (i.e. horizontal or pointing to the front or rear) with strong. A similar association occurs between secondary ridges and ridge strength ($\chi^2 = 7{\cdot}14$, 2 D.F.). As regards complexity of pattern, the presence of forking is negatively associated with the presence of islands ($P = 0{\cdot}0056$), so suggesting that they measure different

Table 7. *Palatal arch*

	Swazi		Greek		
	n	%	*n*	%	
			Anterior view		
Size					
Narrow	—	—	54	20·1	
Medium	7	5·9	174	64·7	$\chi^2 = 212.$
Broad	110	94·1	41	15·2	
			269		
Shape					
Trapeze	24	20·5	64	23·8	
Dome	83	71·0	195	72·5	NS
Cupola	10	8·5	10	3·7	
			269		
			Lateral view		
Size					
Low	50	42·7	54	20·1	
Medium	46	39·3	188	70·2	$\chi^2 = 30{\cdot}7$ (2)
High	21	17·9	26	9·7	
			268		
Shape					
Sloping	42	35·9	184	68·7	
Concave	29	24·8	26	9·7	$\chi^2 = 37{\cdot}3$ (2)
Convex	46	39·3	58	21·6	
			268		
			Superior view		
Size					
Narrow	—	—	40	14·9	
Medium	—	—	200	74·6	
Broad	117	100	28	10·5	
			268		
Shape					
Arch	117	100	189	70·5	
U-shaped	—	—	71	26·5	
Pointed	—	—	8	3·0	
			268		

types or degrees of the same phenomenon. As regards the midline structures, there is no significant association between the strength of forking of the palatal raphe and the position at which forking occurs ($\chi^2 = 8{\cdot}39$, 4 D.F.).

The size of the arch as seen from the front shows no significant association with the number of main ridges (either right or left), nor with main ridge strength, nor with regularity of main ridges. The size of the arch as seen from the side shows a slight association only with regularity of ridges ($\chi^2 = 6{\cdot}77$, 2 D.F.), in that if the lateral arch is of middle size there is less irregularity, while there is more if the arch is high. Seen from above, the size of palatal arch similarly shows an association only with regularity of ridges ($\chi^2 = 10{\cdot}64$, 2 D.F.), in that broad palates tend to be associated with irregularity.

As regards arch shape, seen from the front there is no association with the number of main ridges on either right or left, nor with main ridge strength, nor with ridge regularity. However, seen from the side there is a strong association of sagittal shape with the number of main ridges ($\chi^2 = 32{\cdot}3$, 4 D.F.) in that there are fewer main ridges if the palate is sloping, and more if it is convex, and this applies to the number of ridges both on right and left. Sagittal shape, moreover, shows significant association with main ridge strength ($\chi^2 = 18{\cdot}2$, 2 D.F.), in that a sloping palate tends to be associated

(a)

(b)

(c)

(d)

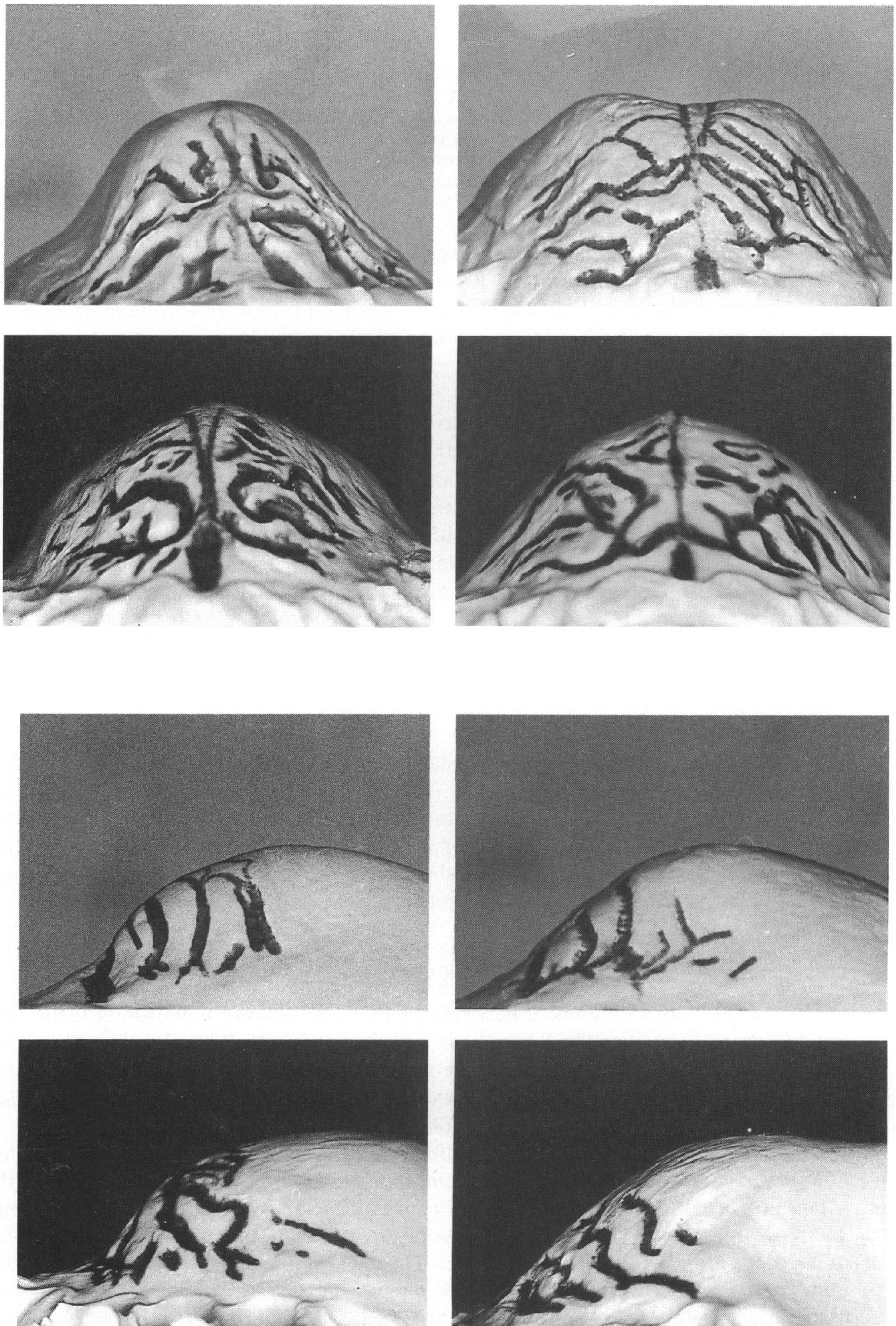

Fig. 3(*a–d*). (*a*) Two Greek palates as seen from the front. (*b*) Two Swazi palates as seen from the front. (*c*) Two Greek palates as seen from the side. (*d*) Two Swazi palates as seen from the side. (*a–d*) on same scale, approx. × 1½.

Table 8. *Correlation coefficients – number of ridges on age*

	Males			Females		
	R	L	Both	R	L	Both
Number of main ridges	0·020	0·040	0·032	0·011	0·000	0·005
Number of secondary ridges	0·007	0·019	0·015	0·012	0·049	0·034

with stronger main ridges, and with main ridge regularity ($\chi^2 = 8{\cdot}68$, 2 D.F.) in that irregularities tend to be associated with convexity of profile. Shape as seen from above shows an association with regularity in that the main ridges tend to be more regular when the palate is arch-shaped, and more irregular when it is pointed or U-shaped.

(*b*) *Swazi*

Internal comparisons among the Swazi are less revealing, presumably because of the greater morphological homogeneity in the Swazi sample. Thus there is no significant association between strength of main and secondary ridges, mainly because of the predominance of strong main ridges, with very few medium, and no weak. There is no significant association of regularity with main or secondary ridge strength. Since forking is present in all cases, its association with other features cannot be assessed. As in the Greeks, there is no significant association between the strength of forking of the palatal raphe and the position at which forking occurs. Since almost all palates are broad, no association of palatal size can be sought with the number of main ridges, their strength or their regularity. There is, however, a significant association of main ridge strength with size of arch as seen from the side, in that high arches tend to have an excess of strong ridges. Main ridge strength also seems to be related to sagittal shape, in that a sloping palate tends to have an excess of strong ridges, just as in the Greek sample.

In the Swazi, each of the 21 variables was analysed by age. Main and secondary ridge counts showed no age association (Table 8), and indeed the only variable to show an age association was the sagittal shape of the palatal arch, where there were fewer sloping profiles in the older subjects.

DISCUSSION

There are obvious differences between the two populations. Comparing them, the impression is given that the Swazi have stronger main ridge development than the Greeks (Fig. 2*b*, *c*) – the main ridges are more numerous, they are stronger and their pattern is more complex. This is at the expense of secondary ridge development. The Swazi midline structures are more complex and the palates broader.

Comparing these interpopulation findings with the small amount of material in the literature, the absence of sex difference in main ridge number in Greeks agrees with what is reported in Japan and Austria (Yamazaki, 1962*a*, *b*; Reuer, 1973), while the Swazi sex difference is similar to, and possibly greater than, that noted by Lysell (1955) in Sweden, and Weldt (1935) in Chile. The Swazi sample has one of the largest numbers of main ridges and the Greek one of the smallest of all so far reported (Austria 4·00: Reuer, 1973; Sweden 4·25: Lysell, 1955; Germany 4·31: Nilles, 1950; North American Whites 4·28: Schultz, 1949; Chileans 4·15: Weldt, 1935; Melanesian males 4·18: Henckel, 1926; American Negro males 4·18: Schultz, 1949; South American Negro 3·71, White 3·41 and Mestizo 3·67: Locchi, 1930; Japanese 4·12 and

4·57: Yamazaki, 1962*a*, *b*; Murakami, 1928). These figures suggest a tendency towards more main ridge development in the populations thought to have broader palates, as does comparison of the present two samples.

The age difference between the Greek and Swazi samples raises the question whether this accounts for the rugal differences. In the literature the consensus of opinion is that the rugae remain fairly stable in number and morphology, except when there is trauma (loss of teeth or persistent pressure which may modify the alignment) or at later ages. The absence of correlation of rugae number, size or strength with age in the Swazi material supports this interpretation. On the other hand, palatal size varies with age with the process of normal growth; in the palate the spurt of growth in width precedes that in length, which in turn precedes that in palatal height, in the prepubertal phase (Jordanov, 1971; Lang & Baumeister, 1984). The fact that the Greek subjects were prepubertal means that some of the subjects may not have completed their palatal growth spurts, so some of the differences in palatal size and shape between the two samples may be due to their age differences. The absence of age associations of palatal size and morphology in the Swazi subjects reflects their maturity – the one feature in which an association emerged was the sagittal shape of the palatal arch, where there was a decreased number of sloping profiles in the older subjects. The Swazi differ from the Greeks also with a decrease in sloping forms, in the same direction as does Reuer's (1973) sample of Austrians. It seems likely that this feature may be related to the different age distributions of the samples.

The findings from the internal analysis of the two populations also differ, largely because of the obscuring effect of Swazi homogeneity in size of palate, the predominance of strong main ridges and the uniform presence of forking. The Greek analysis is more rewarding. But both show significant symmetry between right and left sides, indicating that ridge development is a coordinated feature of the palate as a whole. In both populations there is a suggestion that main and secondary ridges are alternatives, the development of the one at the expense of the other.

As regards their biological significance, both the interpopulation and intra-population comparisons seem to point in the same direction. Interpopulation comparisons suggest an association of main ridge development with palate size, and this also emerges from the association of main ridge strength with higher arch in the Swazi. These associations suggest that the rugae may be the outcome of a common growth process with palatal development, or may be otherwise functionally involved in growth. Embryological studies give some support to this interpretation for they suggest that greater cellular proliferation occurs on the future oral than on the future nasal surface of the vertical palatal processes. The differential growth to which this gives rise may be implicated in the elevation of the palatal processes to form the horizontal palate (Sicher & Bhaskar, 1972). Mitotic activity per unit surface length is increased in the embryonic epithelial thickenings corresponding to the rugae before shelf elevation (Luke, 1984). Such a function would help to explain the population differences observed in this study as well as those in the literature.

It is interesting to speculate whether the low incidence of clefts on lip and palate characteristic of African populations is a reflection of the differential growth in this region suggested by the present paper. According to Kromberg & Jenkins (1982) out of 29 633 consecutive African births, there were only nine babies born with facial clefts. The prevalence rate for the sample was only 0·30 per 1000 births. This rate was similar to that found in Pretoria (0·40 per 1000 births) in the study by Stephenson, Johnson, Stewart & Golding (1966). It appears that there is a low rate for this condition in Blacks in South Africa which would include the Swazi; the prevalence is lower than in other African groups farther north; it is also lower than in whites in Europe and the USA (about 1·8 per 1000: Chung, Rao & Ching, 1980; Czeizel, 1980). On account of the lack of a reference to the prevalence of facial clefts in Greeks these are taken as at European frequency.

SUMMARY

A comparative study is made of the palatal rugae in samples from a Swazi and a Greek population. Intra- and interpopulation comparisons both suggest that development of rugae is coordinated with that of the palate as a whole. Both point to an association of ridge development with size of palate which, it is suggested, reflects local differences in rate of cell division in early embryonic life.

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