Australian Dental Journal 1997;42:(2):129-33

Palatal rugae patterns in Australian Aborigines and Caucasians

Sunita Kapali*
Grant Townsend*
Lindsay Richards*
Tracey Parish*

Abstract

The purpose of this study was to determine whether rugae patterns change with age and to compare the number and pattern of rugae in Australian Aborigines with those of Caucasians. For the longitudinal part of the study, serial dental casts of ten Aborigines, from 6 to 20 years of age, were examined and rugae patterns were recorded. To enable comparisons to be made between different ethnic groups an additional 100 dental casts of Australian Aborigines and 200 casts of Caucasians, ranging in age from 13 to 17 years, were examined. Characteristics observed were number, length, shape, direction and unification of rugae.

The length of rugae increased significantly with age but the total number of rugae remained constant. Thirty-two per cent of rugae showed changes in shape, while 28 per cent displayed a change in orientation. In contrast to studies suggesting that rugae move forward with age, the majority of Aboriginal rugae that changed direction moved posteriorly. Changes in rugae patterns have been assumed to result from palatal growth but alterations in pattern were observed in the Aboriginal sample even after palatal growth had ceased. The mean number of primary rugae in Aborigines was higher than in Caucasians, although more primary rugae in Caucasians exceeded 10 mm in length than in Aborigines. The most common shapes in both ethnic groups were wavy and curved forms, whereas straight and circular types were least common. There was a statistically significant association between rugae forms and ethnicity, straight forms being more common in Caucasians whereas wavy forms were more common in Aborigines.

Key words: Rugae, age changes, ethnic differences, forensic odontology.

(Received for publication May 1996. Accepted July 1996.)

*Department of Dentistry, The University of Adelaide.
Sunita Kapali was the recipient of an 1994-95 Student Scholarship from the Australian Dental Research Fund (now Foundation) Inc.

Introduction

Palatal rugae, also called plicae palatinae transversae and rugae palatina, refer to the ridges on the anterior part of the palatal mucosa, each side of the median palatal raphé and behind the incisive papilla. Rugae patterns have been studied for various purposes, published reports being mainly in the fields of anthropology, comparative anatomy, genetics, forensic odontology, prosthodontics and orthodontics.[1-4]

A histological study of the development of palatal rugae in mice has shown that they develop as localized regions of epithelial proliferation and thickening even before the elevation of the palatal shelves.[5] Subsequently, fibroblasts and collagen fibres accumulate in the connective tissue beneath the thickened epithelium and then assume a distinctive orientation. The collagen fibres running antero-posteriorly within the curve and in concentric curves across the base of each ruga determine the orientation of the rugae.

In human embryos, rugae are relatively prominent and occupy most of the length of the palatal shelves at the time of their elevation.[6] At the 550 mm stage of embryonic development, there are five to seven rather symmetrically disposed ridges, with the anterior ones beginning at the raphé, the others more laterally. Towards the end of intra-uterine life, the pattern of rugae becomes less regular, posterior ones disappearing and those anterior become considerably more pronounced and compressed.[1] The development and differentiation of rugae are more advanced in rats than humans and while they are probably involved in oral function in animals, rugae seem to be attenuating in humans.[7]

Researchers have found the task of classification a difficult aspect of studying rugae. Most studies are based on the systems devised by Lysell,[1] and Thomas and Kotze,[2] although they may differ in detail. The subjective nature of observation and interpretation within and between observers poses a problem. Due to

this lack of complete standardization in interpretation, Thomas and Kotze[2] question the validity of comparisons between different studies.

Controversy still exists about the stability of quantitative and qualitative characteristics of rugae during growth, and the extent of differences between ethnic groups and sexes. Hauser *et al.*[6] have suggested that mean ruga count changes moderately in adolescence, then increases markedly from the age of 35 to 40 years. In contrast, Lysell[1] considered that the number of ruga decreased from 23 years of age onwards. English *et al.*[3] and Peavy and Kendrick[8] noted that the characteristic pattern of the palatal rugae did not change as a result of growth, remaining stable from time of development until the oral mucosa degenerated at death. However, some events can contribute to changes in rugae pattern, including trauma, extreme finger sucking in infancy, and persistent pressure with orthodontic treatment and dentures.[1,9]

It has been suggested that changes in the length of rugae with age result from underlying palatal growth.[1,6,10] However, the anterior rugae do not increase in length after 10 years of age according to Van der Linden.[11] Other qualitative characteristics such as shape, direction and unification remain stable throughout life. Despite the ongoing problem of describing palatal ruga patterns qualitatively and quantitatively, their uniqueness to individuals has been recognized in forensic science as providing a potentially reliable source of identification.[3]

Twin studies have revealed that rugae patterns have an underlying genetic basis.[1] Thomas and Kotze were also able to discern different rugae patterns in southern African populations implying different genetic origins.[12-14]

This study, through longitudinal and cross-sectional approaches, aims to investigate changes of rugae pattern with age in Australian Aborigines and to compare patterns between Aborigines and Caucasians.

Materials and methods

The material for this study consisted of dental casts of Australian Aborigines and Caucasians housed in the Department of Dentistry at the University of Adelaide. All the Aboriginal dental casts were obtained from a group of Aborigines living at Yuendumu in Central Australia. The Caucasian models were collected as part of an ongoing study of dento-facial morphology in Australian twins and their families. The longitudinal part of the study included 10 Aborigines (5 males and 5 females) ranging in age from 6 to 20 years. The cross-sectional study included 100 Aborigines (50 males and 50 females) and 220 Caucasians (110 males and 110 females).

The ethical guidelines used by the National Health and Medical Research Council (of Australia) were followed in obtaining all dental models and informed consent was obtained from participants.

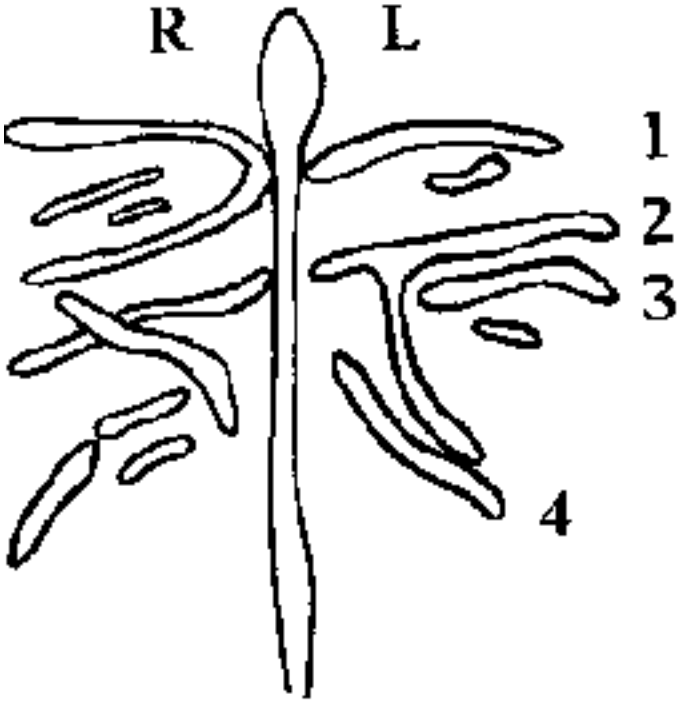

Fig. 1.–Numbering of palatal rugae.

The classification used to describe the rugae patterns was based on those described by Lysell[1] and Thomas and Kotze[2] (Fig. 1).

To assess intraobserver variation in interpretation, double determinations were performed for 20 subjects. There were few discrepancies, percentage concordance between repeat observations exceeding 95 per cent. Most discrepancies involved characterization of secondary and fragmentary rugae, perhaps because of their size. Measurement errors of the length of rugae in the longitudinal study ranged from 0.5-1 mm. Errors in length were small in the cross-sectional study because measurements were categorized rather than retaining their quantitative scale.

Classification of rugae

Rugae length was recorded under magnification with a slide calliper to an accuracy of 0.05 mm following the descriptions of Thomas and Kotze.[12]

Having determined the length of all the rugae, three categories were formed:

1. Primary rugae: (A-5 to 10 mm; B-10 mm or more)
2. Secondary rugae: 3-5 mm
3. Fragmentary rugae: less than 3 mm.

As one of the objectives of the longitudinal study was to observe changes in length with age, all rugae more than 1 mm long were recorded under the fragmentary ruga category.

The shapes of individual rugae were classified into four major types: curved, wavy, straight and circular (Fig. 2).

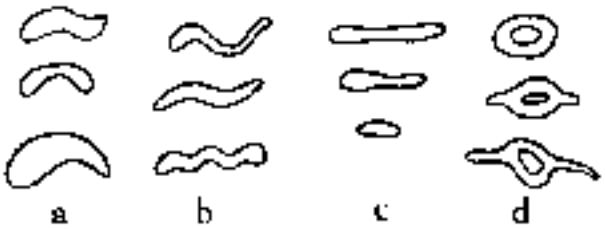

Fig. 2.–Various shapes of rugae: a, curved. b, wavy. c, straight. d, circular.

Straight types ran directly from their origin to termination. The curved type had a simple crescent shape which curved gently. Evidence of even the slightest bend at the termination or origin of a ruga led to a classification as curved. The basic shape of the wavy rugae was serpentine; however, if there was a slight curve at the origin or termination of a curved rugae it was classified as wavy. To be classified as circular, a ruga needed to display a definite continuous ring formation.

The direction of each primary ruga was determined by measuring the angle between the line joining its origin and termination and a line perpendicular to the median raphé. Forward-directed rugae were associated with positive angles, backward-directed rugae with negative angles, and perpendicular rugae with angles of zero degrees.

Unification occurs when two rugae are joined at their origin or termination. Unifications in which two rugae began from the same origin but immediately diverged were classified as diverging. Rugae with different origins which joined on their lateral portions were classified as converging.

Associations between rugae forms and ethnicity were tested using chi-squared analysis, while comparisons of ruga length within individuals at different ages were made with paired *t* tests. Comparisons of ruga lengths between males and females and between Aborigines and Caucasians were based on unpaired *t* tests.

Results

Longitudinal

The total number of rugae did not change over the age range observed in the study. However, all subjects showed a change in shape or direction of at least one ruga with increasing age. Among the 32 per cent of rugae that changed shape, the most common changes were from wavy to curved (20 per cent), straight to curved (18 per cent), circular to curved (12 per cent), curved to circular (8 per cent).

Among the 26 per cent of rugae that changed orientation, the most common changes were from forward to perpendicular (28 per cent), from perpendicular to backward (10 per cent), from perpendicular to forward (23 per cent), from backward to forward (17 per cent), and from forward to backward (13 per cent). Fifty-three per cent of rugae that changed direction moved backward. Changes in unification were very rare with only 2 per cent of rugae changing their type.

Table 1. Change in length of rugae with age in 10 Australian Aborigines (right side only in mm)

Ruga	Youngest age (6 years)		Oldest age (20 years)	
	Mean	SD	Mean	SD
1	9.4	3.06	10.1	2.77
2	9.7	2.59	11.3*	1.07
3	8.2	5.28	8.7	5.90
4	6.6	3.05	8.2*	3.62
5	6.2	2.86	8.2*	3.72
6	5.0	3.91	6.7*	4.86
7	5.7	3.80	6.3	4.75
8	8.1	3.83	10.0*	5.18

*Significant increase at $p<0.05$ level using paired *t* test.

Table 1 presents summary data of the lengths of the primary rugae over the six to 20 year age range in the Aboriginal sample. As there were no systematic differences between sides, summary statistics for the right side only are presented. There was a significant increase in length of the majority of rugae between the youngest and oldest ages of the 10 individuals included in the longitudinal study. The magnitudes of length changes however, did not differ significantly between males and females.

Cross-sectional

The average number of rugae in the Aboriginal sample showed no significant differences between the sexes, being 5.0 and 4.9 for males and females respectively. Furthermore, no significant difference in number of rugae between right and left sides was apparent for either sex.

The mean number of primary rugae was significantly higher in Aborigines than in Caucasians ($p<0.05$). The percentage of primary rugae that were longer than 10 mm was greater in Caucasians than Aborigines (63 per cent compared with 56 per cent). Table 2 compares the results of the present study with data published for other populations. No statistical analysis was attempted between the results of the present study and other published data due to

Table 2. Average number of palatal rugae in different human populations

Ethnic group	No. of subjects	Sex	Age range (years)	Number of rugae		
				Left	Right	Mean
Japanese	50	Male	–	4.7	4.7	4.7
	50	Female		4.3	4.5	4.5
Central	50	Male	10-50	4.3	4.2	4.3
Europeans	50	Female		4.3	4.4	4.4
Swedes	50	Male	21-24	4.5	4.3	4.4
	50	Female		4.3	3.9	4.1
Australian	50	Male	14-20	5.2	4.8	5.0
Aborigines	50	Female		5.2	4.6	4.9
Australian	110	Male	11-57	4.3	4.3	4.3
Caucasians	110	Female		4.3	4.3	4.3

Data from Lysell[1] and present study.

Table 3. Frequencies of different rugae forms in Australian Aborigines and Caucasians*

Shape	Aborigines	Caucasians
Curved	221 (23.2)	298 (25.8)
Straight	34 (3.6)	176 (15.2)
Wavy	531 (55.8)	469 (40.6)
Circular	34 (3.6)	33 (2.9)
Unifications	132 (13.9)	180 (15.6)

*Percentages in parentheses.
Chi-squared value=99.9 with four degrees of freedom, $p<0.001$.

the problems associated with inter-observer variability.

Table 3 presents the frequencies of major rugae forms, including unifications, in Australian Aborigines and Caucasians. The most common shapes in both ethnic groups were wavy and curved forms, whereas straight and circular types were least common. Overall there was a statistically significant association between rugae forms and ethnicity (chi-squared value=99.9 with four degrees of freedom, $p<0.001$). Straight forms were more common in Caucasians than Aborigines (15.2 per cent compared with 3.6 per cent), while wavy forms were more common in Aborigines (55.8 per cent compared with 40.6 per cent).

Discussion

The finding that the total number of rugae did not change throughout early childhood and adolescence coincides with other longitudinal studies in different ethnic groups.[1,6,15] According to Lysell[1] the total number of rugae remains unchanged up to the age of 23 years and decreases thereafter. As the oldest age group observed in this study was 20 years, possible later changes in rugae incidence could not be verified.

Qualitative changes in rugae that were studied included shape, direction and unification. Although minor changes in shape were noted, only 32 per cent of rugae changed shape. Therefore, despite the fact that subjects were studied where palatal growth, tooth loss and tooth movement were all taking place (changes from primary, through mixed, to permanent dentition), the incidence of change in rugae shape was low.

Lysell[1] suggests that there is a tendency for the backward direction of rugae to decrease with age. He attributed this change to an increase in the width of the palate and forward movement of the teeth in relation to the rugae, resulting in rugae being located in a wider and shallower part of the palate than originally. Another possible explanation given for this tendency is the forward movement of lateral parts of the rugae in connection with forward growth of dental arch. In contrast to Lysell's suggestion, the authors noted that 53 per cent of the rugae that changed direction actually moved backwards. This indicates a high percentage of rugae moving in a posterior direction in Aborigines. Could this be attributed to the different ethnicity of the subjects in each study? With difference in ethnicity come differences in the pattern and extent of growth of the palate, genetic variation, and different patterns of movement of teeth due to crowding and wear pattern. Dohke and Osato[9] have also suggested that direction of rugae is influenced by the formation of the dental arch associated with replacement of teeth and by growth and developmental changes in the palate. However, to verify that the backward movement of rugae is a special characteristic of Aborigines, more accurate measurements would be required. Future studies could try to measure variation in direction by recording angular changes rather than classifying rugae direction in general terms.

The material available for this study enabled the assessment of changes during a relatively short developmental period (from childhood to late adolescent only). Qualitative changes in rugae were observed even after significant growth in palatal dimensions ceased to occur. Longer term follow-up is needed to reveal a more conclusive relationship between palatal developmental changes and rugae patterns. It would also be interesting to see the extent and pattern of changes in rugae in the same subjects followed into adulthood, where growth changes have already ceased and loss of teeth has not occurred.

Thus it seems that the primary changes in rugae with age relate to their length only. If ruga development is co-ordinated with differential growth of the palate, is it likely that palatal changes would only affect direction of rugae but not shape? More insight could be shed on this dilemma if different regions of palate could be identified according to their pattern of growth and the effect of growth changes on rugae that lie within these zones could be observed. At present, it is unclear whether age changes of palatal rugae are governed by different underlying factors, for example, rates of cell division during the embryonic period or co-ordination with palatal growth and development later in life.

The number of primary rugae in Australian Aborigines was found to be higher than in Caucasians. The mean number of rugae in Aborigines was also higher than reported for other ethnic groups. However, Caucasians tended to show a higher proportion of rugae that are longer than 10 mm compared with Aborigines. The trends in mean number of rugae between different populations suggest a tendency for greater ridge development qualitatively and quantitatively in populations with broader palates.[6] This finding is consistent with this suggestion as Aborigines generally have broad palates. However, this does not explain the observation that more rugae were longer than 10 mm in Caucasians compared with Aborigines. This contradictory finding may be due merely to the method of categorizing length measurements rather than analysing direct measurements.

Analysis of the number of Aboriginal primary rugae failed to reveal any significant differences between sides or sexes. This observation conflicts with Dohke and Osato[9] who reported fewer rugae on the right side of the palate than the left, and that females had fewer rugae than males. These authors claim that this was due to the phenomenon of regressive evolution dominating the right side of the palate and being more evident in females. The inability to demonstrate this phenomenon may be due to the methodology used. The cross-sectional study did not include secondary rugae and it is the secondary rugae that Dohke and Osato[9] considered to demonstrate regressive tendencies, leading to bilateral differences.

Comparisons of shape and unification of primary rugae between Aborigines and Caucasians failed to indicate any systematic trends. Maybe these characteristics of rugae lack discriminatory ability. Larger sample sizes and comparisons of patterns of secondary and fragmentary rugae between different ethnic groups, rather than primary rugae alone, could be worthwhile. Thomas and Kotze[13] also noted that although primary rugae have been more widely studied than secondary and tertiary rugae, they do not possess strong discriminatory ability between different human populations.

Apart from problems of intra-observer discrepancies in reading rugae patterns, there is no doubt that even greater discrepancies could exist between observers. The existence of this unreliability brings into question the present usefulness of descriptive rugoscopy in fields such as forensic science. Although researchers have confirmed the potential value of rugae in personal identification,[3] it is important that exact reproductions of patterns (for example, casts or photographs) are available and that classification systems are further refined so that they are reliable but relatively simple to apply.

Acknowledgement

The support of a Student Scholarship awarded to Ms Kapali by the Australian Dental Research Fund Inc. (now Foundation) is gratefully acknowledged.

References

1. Lysell L. Plicae palatinae transversae and papilla incisiva in man: a morphologic and genetic study. Acta Odont Scand 1955;13:Suppl 18:1-137.
2. Thomas CJ, Kotze TJvW. The palatal rugae pattern: a new classification. J Dent Assoc South Afr 1983;38:153-7.
3. English WR, Robinson SF, Summitt JB, Oesterle LJ, Brannon RB, Morlang WM. Individuality of human palatal rugae. J Forens Sci 1988;33:718-26.
4. Almeida MA, Phillips C, Kula K, Tulloch C. Stability of the palatal rugae as landmarks for analysis of dental casts. Angle Orthod 1995;65:43-8.
5. Luke DA. Development and growth of palatal rugae in the mouse. Acta Anat 1988;133:41-4.
6. Hauser G, Daponte A, Roberts MJ. Palatal rugae. J Anat 1989;165:237-49.
7. Thomas CJ, Rossouw RJ. The early development of palatal rugae in the rat. Aust Dent J 1991;36:342-8.
8. Peavy DC, Kendrick GS. The effects of tooth movement on the palatine rugae. J Prost Dent 1967;18:536-42.
9. Dohke M, Osato S. Morphological study of the palatal rugae in Japanese. 1. Bilateral differences in the regressive evolution of the palatal rugae. Jpn J Oral Biol 1994;36:126-40.
10. Simmons JD, Moore RN, Erickson LC. A longitudinal study of anteroposterior growth changes in the palatine rugae. J Dent Res 1987;66:1512-5.
11. Van der Linden FPGM. Changes in the position of posterior teeth in relation to ruga points. Am J Orthod 1978;74:142-61.
12. Thomas CJ, Kotze TJvW. The palatal ruga pattern in six southern African human populations, Part I: a description of the populations and a method for its investigation. J Dent Assoc South Afr 1983;38:547-53.
13. Thomas CJ, Kotze TJvW. The palatal ruga pattern in six southern African human populations, Part II: inter-racial differences. J Dent Assoc South Afr 1983;38:166-72.
14. Thomas CJ, Kotze TJvW. The palatal ruga pattern in six southern African human populations, Part III: an evolutionary perspective. J Dent Assoc South Afr 1983;38:173-6.
15. Thomas CJ. Incidence of primary rugae in Bushman juveniles. J Dent Res 1972;51:676.

Address for correspondence/reprints:
Professor G. Townsend,
Department of Dentistry,
The University of Adelaide,
South Australia 5005.