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PAPER

ODONTOLOGY

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Morphological Pattern of Palatal Rugae in Children of Davangere

ABSTRACT: The aim of this study was to identify and compare the rugae pattern between males and females of two different communities in the city of Davangere, Karnataka, India, which may be an additional method of identification in cases of crimes or communal riots. Elastomeric impressions of the maxillary arch of 100 selected children were made; casts were poured in Type IV stone. The method of identification of rugae pattern followed was that of Lysell and Thomas and Kotze, which includes the number, shape, direction, and unification of rugae. The study revealed no significant difference in the total number or length of rugae between the two communities and sexes. However, with regard to shape and unification, females showed a significantly higher diverging rugae type while males had a significant number of circular and converging type of rugae. Also, discrimination function analysis allowed a moderate differentiation of the population. Hence, the rugae pattern can be an additional method of differentiation in conjunction with the other methods such as visual, fingerprints, and dental characteristics in forensic sciences.

KEYWORDS: forensic science, forensic dentistry, palatal rugae, dental casts, discriminant function analysis, human identification

For centuries, anatomists have shown interest in the evolutionary development of the folds of tissue found in the roof of the human mouth—the palatine rugae (1). 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 raphe and behind the incisive papilla (2).

The earliest reference to rugae was in an anatomy text by Winslow in 1732 and was first illustrated by Santorini in 1775 (3). Lysell defined the boundaries of this transverse ridge like wrinkles or folds extending outward on both sides of the raphe of the palate. He called the most obvious rugae primary 0 rugae, which number on the average of four on each half of the palate. Lund observed that a connective tissue core is deeply imbedded between the submucosa fatty tissue and stratum reticulum of the palate. This core represents a foundation over which the substance of the rugae builds up to become a fold-like projection in the roof of the mouth (1).

In the human embryo, they are relatively prominent, occupying much of the length of the palatal shelves at the time of their elevation (4). Toward the end of intrauterine life, the pattern of rugae becomes less regular, posterior ones disappearing and those anterior becoming considerably more pronounced and compressed (2). At birth, the palatine rugae are well formed, and the pattern of orientation typical for the person is present (5). Carrea indicated that a rugae pattern had been formed by the 12th to 14th week of intrauterine life, and he thought that it remained stable from this time throughout life (4).

Sassuouni stated that no two palates are alike in their configuration and that the palatoprint did not change during growth. Ritter studied the rugae of twins and found that the pattern was similar but not identical. Hausser studied children from birth to 9 years and found that the characteristic picture of the palate does not change as a result of growth. Leontsinis ascertained that rugae do not change from the time they develop until the oral mucosa degenerates at death (3).

The use of palatal rugae was suggested as an alternate method of identification in 1889 by Harrison Allen (3). When traffic accidents, acts of terrorism, communal riots, or mass disasters occur in which it is difficult to identify a person according to fingerprints or dental records, rugae may be an alternative method of identification (5). Rugae are protected from trauma by their internal position in the head, and they are insulated from heat by tongue and the buccal fat pads (3).

Investigations have been carried out to study the thermal effects and the decomposition changes on the palatal rugae of panfacial third-degree burn victims and have concluded that most victims did not sustain any palatal rugae pattern changes, and when changes were noted, they were less pronounced than in the generalized body state. Furthermore, the ability of palatal rugae to resist decomposition changes for up to 7 days after death was also noted (6). Thus, palatal rugae appear to possess the features of an ideal forensic identification parameter—uniqueness, postmortem resistance, and stability. Hence, they can be used in postmortem identification provided an antemortem record exists. In addition, differences in rugae pattern have been found in relatively similar populations (5).

Therefore, this study ventured to examine a limited sample of children from Davangere city, Karnataka, India with the objectives of providing preliminary data on (i) possible difference in rugae pattern between two different communities (Hindu and Muslim), (ii) possible difference in rugae pattern between males and females, and (iii) effectiveness of rugae pattern in identifying the populations using discriminant function analysis.

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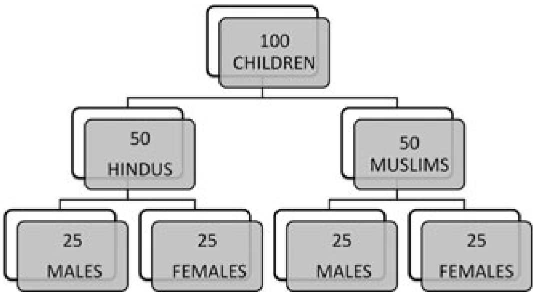

FIG. 1—*Sample selection and categorization.*

Methodology

A total number of 100 subjects were selected among the children of Davangere city, Karnataka, India (Fig. 1). The children were in the age group of 7–9 years with a mean of 8 years. All subjects were healthy individuals free of congenital abnormalities, inflammation, trauma, or orthodontic treatment. The ethical guidelines were followed in obtaining all dental models, and informed consent was obtained from participants.

The Impressions

An elastomeric impression material was used on an appropriate custom-made tray for the maxillary dental arch for all subjects. All instructions by the manufacturers were followed. The impressions were then poured into Type IV stone. All casts were free of air bubbles or voids especially at the anterior third of the palate (Fig. 2).

Method of Identification

The classification used to describe the rugae patterns was based on those described by Lysell and Thomas and Kotze (7).

Classification of Rugae

Rugae length was recorded under magnification with a slide caliper to an accuracy of 0.05 mm following the descriptions of Thomas and Kotze. Having determined the length of all the rugae, three categories were formed:

FIG. 2—*Maxillary dental cast highlighting various rugae patterns.*

- Primary rugae: (5 mm or more).
- Secondary rugae: 3–5 mm.
- Fragmentary rugae: less than 3 mm.

Further on, the fragmented rugae were not considered for any of the categorizations.

The shapes of individual rugae were classified into four major types: curved, wavy, straight, and circular (Fig. 3). Straight types ran directly from their origin to termination. The curved type had a simple crescent shape that curved gently. Evidence of even the slightest bend at the termination or origin of a rugae 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 curved rugae, it was classified as wavy. To be classified as circular, a ruga needed to display a definite continuous ring formation (2).

The direction of each primary rugae was determined by measuring the angle between the line joining its origin and termination and a line perpendicular to the median raphe (Fig. 4). Forward-directed rugae were associated with positive angles, backward-directed rugae with negative angles, and perpendicular rugae with angles of zero degrees (2).

Unification occurs when two rugae are joined at their origin or termination, that is a rugae is having two arms. Thomas and Kotze have categorized two armed primary rugae as branches or unification depending upon the length of their origin. This study has, however, categorized all forms of unified and branched rugae as unifications (8). 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 (Fig. 5).

To avoid intraobserver variation in interpretation, double determinations were performed with the help of a second examiner for all samples. The discrepancies were minimal and most of them involved characterization of secondary and fragmentary rugae,

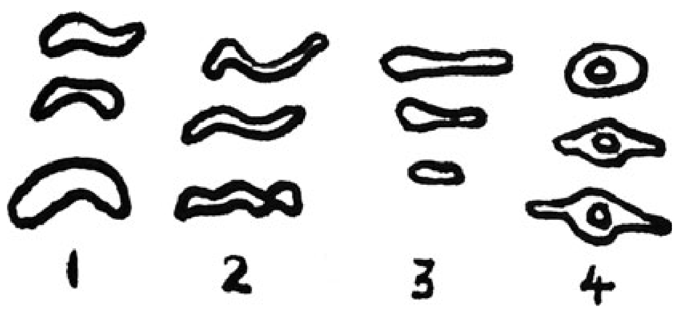

FIG. 3—*Various shapes of rugae: 1—curved; 2—wavy; 3—straight; 4—circular.*

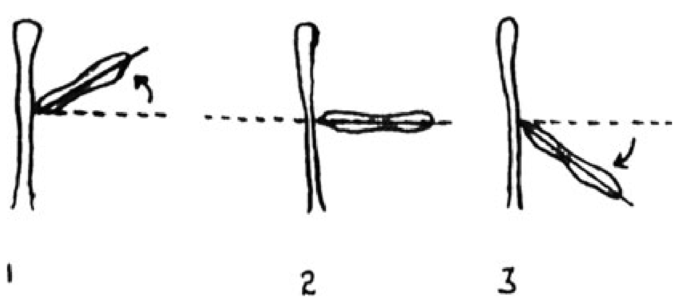

FIG. 4—*Direction of primary rugae: 1—forward directed; 2—perpendicular; 3—backward directed.*

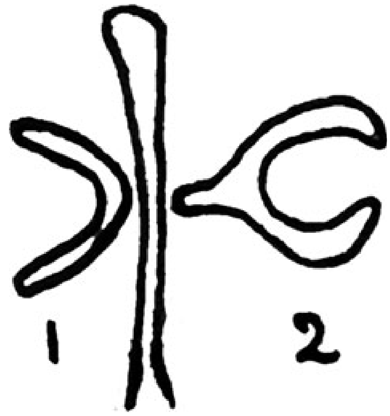

FIG. 5—*Rugae unification: 1—diverge; 2—converge.*

TABLE 1—*Chi-square analysis for assessing difference in rugae pattern between two different communities.*

	Hindu		Muslim		Significance	
Rugae Characteristics	Mean	SD	Mean	SD	*t* Value	*p* Value
Length						
Primary	7.8	1.3	7.6	1.7	0.66	0.51
Secondary	2.9	1.8	2.8	1.7	0.29	0.77
Fragmented	1.56	1.36	1.60	1.46	0.34	0.74
Shape						
Curved	2.5	1.4	2.6	1.5	0.34	0.74
Wavy	5.8	1.8	5.3	1.6	1.47	0.14
Straight	1.8	1.4	1.9	1.2	0.38	0.71
Circular	0.6	0.6	0.5	0.6	0.83	0.41
Direction						
Forward	3.90	1.71	3.88	1.9	0.28	0.78
Backward	2.3	1.5	2.4	1.8	0.30	0.76
Perpendicular	1.7	1.4	1.3	1.3	1.48	0.14
Unification						
Diverging	0.9	0.9	1.0	1.0	0.46	0.65
Converging	0.8	0.9	0.9	0.8	0.59	0.86

perhaps because of their size. Errors in length were small in the study because measurements were categorized rather than retaining their quantitative scale. Association between rugae patterns and two communities as well as rugae pattern and gender was tested using chi-square analysis and a stepwise discriminant function developed using the SPSS 10.0 statistical package (SPSS Inc., Chicago, IL).

Results

The rugae characteristics showed no significant difference between right and left sides for either communities or sex. Henceforth, the tabulations were made combining both right and left sides. The frequency of occurrence of different rugae patterns in the classified populations is described in Tables 1 and 2. The mean number of primary rugae is more as compared to secondary or fragmented in all the groups, but not significant. When the shape of the rugae is considered, wavy and curved rugae are the most prevalent forms in all the groups, followed by straight rugae. The frequency of circular rugae is least; however, it showed a statistically significant difference between sexes combining both populations, being 0.72 and 0.36 for males and females, respectively, ($p < 0.005$) as per the chi-square analysis. Tables 3 and 4 show discriminant function analysis of rugae pattern. Discriminant function is used to determine how well a function that includes rugae distinguishes between religions or between genders. The *F*-ratios indicated that the differences between the sexes in measurements such as circular, converging, and diverging were

TABLE 2—*Chi-square analysis for assessing sex difference in rugae pattern.*

	Males		Females		Significance	
Rugae Characteristics	Mean	SD	Mean	SD	*t* Value	*p* Value
Length						
Primary	7.74	1.482	7.66	1.586	0.32	0.75
Secondary	2.94	2.004	2.8	1.429	0.29	0.77
Fragmented	1.68	1.435	1.48	1.374	0.71	0.48
Shape						
Curved	2.74	1.482	2.44	1.445	1.03	0.31
Wavy	5.3	1.843	5.82	1.48	1.51	0.13
Straight	1.98	1.301	1.78	1.234	5.20	0.001
Circular	0.72	0.671	0.36	0.563	2.30	0.05
Direction						
Forward	3.72	1.863	4.06	1.766	1.08	0.28
Backward	2.46	1.487	2.16	1.867	0.88	0.38
Perpendicular	1.56	1.373	1.42	1.326	0.74	0.46
Unification						
Diverging	0.72	0.809	1.2	1.01	2.76	0.01
Converging	1.1	0.863	0.64	0.776	2.94	0.01

TABLE 3—*Stepwise discriminant function analysis of the different rugae patterns—Community.*

Variables Entered	Wilks' Lambda	Exact *F* Statistic	df1	df2	Significance
Tests of equality of group means					
Primary	0.996	0.426	1	98	0.52
Secondary	1.000	0.030	1	98	0.86
Fragmented	1.000	0.020	1	98	0.89
Curved	0.999	0.116	1	98	0.74
Wavy	0.979	2.054	1	98	0.16
Straight	0.998	0.223	1	98	0.64
Circular	0.999	0.096	1	98	0.76
Forward	1.000	0.003	1	98	0.96
Backward	0.999	0.087	1	98	0.77
Perpendicular	0.984	1.608	1	98	0.21
Diverging	0.993	0.719	1	98	0.40
Converging	0.999	0.124	1	98	0.73

Wilks' lambda: For testing the quality of group centroids. It is the relating of variances within and between groups. Smaller value indicates that group means differ.

Function coefficients are used to assign or classify cases into groups.

TABLE 4—*Stepwise discriminant function analysis of the different rugae patterns—Sex.*

	Wilks' Lambda	Exact *F* Static	df1	df2	Significance
Tests of equality of group means					
Primary	0.999	0.068	1	98	0.795
Secondary	0.998	0.162	1	98	0.688
Fragmented	0.995	0.507	1	98	0.478
Curved	0.989	1.05	1	98	0.308
Wavy	0.976	2.419	1	98	0.123
Straight	0.994	0.622	1	98	0.432
Circular	0.921	8.445	1	98	0.005
Forward	0.991	0.877	1	98	0.351
Backward	0.992	0.79	1	98	0.376
Perpendicular	0.997	0.269	1	98	0.605
Diverging	0.934	6.877	1	98	0.01
Converging	0.926	7.852	1	98	0.006

statistically significant ($p < 0.001$). Wilks' lambda determines the relative order in which the variables enter the function. The program default criterion was used to determine the F values (1.0) to enter and remove a variable.

Tables 5 and 6 depict the unstandardized and standardized coefficients, structure matrix, group centroids, and sectioning points that decide the specified group with the discriminant function. Standardized coefficients determine the relative contribution of each of the predictor variables to the function and assume no intercorrelation between variables. The structure matrix describes the magnitude of relation between the function and the variables entered while the group centroids represent the average discriminant scores for each population. Sectioning point is the average of the group centroids. To determine the population group to which an unidentified individual belongs, the number of each type of rugae pattern is multiplied with the respective unstandardized coefficient and added to the constant.

To determine the population group to which an unidentified individual belongs, the number of each type of rugae (e.g., primary/wavy/forward/diverging) is multiplied with the respective unstandardized coefficient and added to the constant. If the value obtained is greater than the sectioning point, the individual is considered to be Hindu in case of community and male in case of sex. If the value obtained is less than the sectioning point, the individual is considered to be Muslim in case of community and female in case of sex. The farther the discriminant score is from the sectioning point, the higher the probability of correct identification (posterior probability).

Hence, the method for calculating the unidentified population is,

Religion

$$Z = -2.833 - 0.138(\text{Primary rugae}) + 0.316(\text{Secondary rugae}) + 0.156(\text{Fragmented rugae}) - 0.293(\text{Curved}) + 0.171(\text{Wavy}) - 0.497(\text{Straight}) + 0.236(\text{Circular}) + 0.532(\text{Forward}) + 0.415(\text{Backward}) + 0.912(\text{Perpendicular}) - 0.14(\text{Diverging}) - 0.2(Converging)$$

Gender

$$Z = -0.518 - 0.86(\text{Primary rugae}) - 0.697(\text{Secondary rugae}) + 0.051(\text{Fragmented}) + 0.734(\text{Curved}) + 0.422(\text{Wavy}) + 0.897(\text{Straight}) + 1.378(\text{Circular}) + 0.224(\text{Forward}) + 0.388(\text{Backward}) + 0.268(\text{Perpendicular}) - 0.431(\text{Diverging}) + 0.726(\text{Converging})$$

The accuracy with which discriminant function can identify a population is given in Tables 7 and 8. The results indicate the expected accuracy of identifying an individual from each population group by the function derived from the entire sample.

TABLE 5—*Discriminant function coefficients for rugae that entered analysis—Community.*

Variable	Unstandardized Coefficients	Structured Matrix	Standardized Coefficients	Hindu	Muslim	Sectioning Point
Length						
Primary	−0.138	0.231	−0.211	0.282	−0.282	0.000
Secondary	0.316	0.061	0.551			
Fragmented	0.156	−0.050	0.220			
Shape						
Curved	−0.293	−0.120	−0.431	0.282	−0.282	0.000
Wavy	0.171	0.508	0.286			
Straight	−0.497	−0.167	−0.631			
Circular	0.236	0.110	0.152			
Direction						
Forward	0.532	0.019	0.970	0.282	−0.282	0.000
Backward	0.415	−0.105	0.702			
Perpendicular	0.912	0.449	1.223			
Unification						
Diverging	−0.514	−0.301	−0.485	0.282	−0.282	0.000
Converging	−2.833	−0.125	−0.528			

TABLE 6—*Discriminant function coefficients for rugae that entered analysis—Sex.*

Variable	Unstandardized Coefficients	Structured Matrix	Standardized Coefficients	Male	Female	Sectioning Point
Length						
Primary	−0.860	0.046	−0.860	0.570	−0.570	0.000
Secondary	−0.697	0.071	−0.697			
Fragmented	0.051	0.125	0.051			
Shape						
Curved	0.734	0.180	0.734	0.570	−0.570	0.000
Wavy	0.422	−0.273	0.422			
Straight	0.897	0.138	0.897			
Circular	1.378	0.510	1.378			
Direction						
Forward	0.224	−0.164	0.224	0.570	−0.570	0.000
Backward	0.388	0.156	0.388			
Perpendicular	0.268	0.091	0.268			
Unification						
Diverging	−0.431	−0.460	−0.431	0.570	−0.570	0.000
Converging	0.726	0.492	0.726			

TABLE 7—*Population function accuracy of the discriminant function for community.*

	Hindu	Muslim
Number of cases	32/50	31/50
%	64	62

TABLE 8—*Population identification accuracy of the discriminant function for gender.*

	Male	Female
Number of cases	37/50	36/50
%	74	72

Here, sex of the individual is more accurately diagnosed than community with males having better prediction accuracy than females.

Discussion

Population differences pose the question as to how much is attributable to genetic differences and how much is the result of environmental effects. Twin studies have revealed that rugae pattern has an underlying genetic basis. According to Luke, the rugae develop as localized regions of epithelial proliferation and thickening. Fibroblast and collagen fibers then accumulate in the connective tissue beneath the thickened epithelium and assume distinct orientation. It is plausible that certain, as yet unidentified, genes influence orientation of the collagen fibers during embryogenesis and postnatal growth and govern rugae pattern in different populations (8). Thomas and Kotze postulated that an evolutionary trend exists in which the rugae of primates, including man, are becoming attenuated (9,10). This study was carried out under the presumption that some amount of environmental influences such as food habits along with genetic factor over the decades would have influenced the rugae pattern, thus would give a difference in the pattern between the two communities and sexes.

The most difficult aspect of observing rugae is the application of the classification. While its characteristics have been defined as fully as possible, the interpretation of features is sometimes difficult (11). It has been suggested elsewhere that a classification system that is simple and reliable be used in rugae studies. The classification method used in this study was found to be more practical and easiest to apply compared with other methods such as those of Houser et al. and of Reuer (12). With this classification, difference could be appreciated between population groups with certain patterns being more significant, thus indicating the applicability of rugae pattern in population differentiation.

Population Variation in Rugae Pattern

Since Lysell's study in 1955, specific anatomical investigations of the rugae pattern have been reported by many authors. They report that the rugae number stays unchanged throughout life, that the size and detailed arrangements change with growth of the palate, that there are interracial differences, that there are sex differences, and that there are no sex differences (11).

In the present study, no significant difference could be found in total number of rugae between two communities or sexes. Similar finding was observed with respect to primary rugae pattern. Thomas and Kotze 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 (13). However, this observation conflicts with Dohke and Osato who reported that among the Japanese, females had fewer rugae than males and that the right side of the palate had fewer rugae than the left (14).

Comparisons of shape and unification of rugae between two religions failed to give any statistically significant trends. But when the comparison was made between the sexes, presence of the circular type of rugae was found to be statistically higher in males than in females. This was similar to the findings by Fahmi et al. (12) who studied rugae pattern between males and females in the Saudi population. Kapali et al. (2) report higher wavy rugae in Australian aborigines while straight rugae, although constituting low percentages in aborigines and Caucasians, are more in the latter. Yet another finding in our study was that the divergent rugae was higher in females ($p < 0.01$) and the converging rugae was higher in males ($p < 0.01$). On the contrary, Fahmi et al. (12) had found converging pattern to be higher in females. In another study, comparisons of rugae patterns between African and European population revealed that the former had statistically greater numbers unifications and circular rugae.

Comparative studies, therefore, show varying pattern of differences in palatal rugae between populations. Owing to apparent lack of systematic trends, some authors conclude that rugae pattern does not possess discriminatory ability. To ascertain this, we subjected the rugae pattern to discriminant function analysis. In our study, the accuracy with which the discriminant function can identify a population is 64% and 62% to consider it as Hindu or Muslim, and it is 74% and 72%, respectively, for males and females when sexual identification has to be made.

Conclusion

The fingerprint-like uniqueness of rugae to each individual has become accepted as a possible aid to person identification. On a collective basis, the palatal rugae pattern has shown population-specific tendencies. However, although researchers have confirmed the potential value of rugae in personal identification, it is important that exact reproductions of patterns (for example, casts or photographs) should be available and that classification systems are further refined so that they are reliable but relatively simple to apply. Certain features of the rugae in this study have shown themselves to be discriminatorily strong in differentiating between human population groups. The prevalence of some of these features has shown to contain evolutionary implications. The authors recognize that the above-mentioned interpretations are precluded by limited sample size and therefore the preceding analysis should only be considered as preliminary.

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