ORIGINAL RESEARCH

Assessment of Palatal Rugae Patterns among Different Age Groups: An Institution-based Study

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ABSTRACT

Introduction: Due to the distinctive anatomy of the human dentition, the teeth and palatal rugae of the oral cavity have a vital role in forensic dentistry. In certain situations, when teeth are missing due to trauma, palatal rugae have been used to help in recognition and matching of the individual. The palatine rugae pattern is unique for each human being and so can be used in identification. Age, sex, and even ethnic identity can be determined using rugoscopy.

Aim: To discover whether there are any specific rugal patterns pertaining to any age group, gender, and ethnicity, and whether these can be used to assess these parameters during forensic examination.

Materials and methods: Totally, 100 males and 100 females of Kerala origin and 12 non-Keralite males and females each were assessed in this study. Data from the right side and left side were collected separately.

Results: The results presented here provide data on the direction, shape, length, unification, and number of rugae. Statistical Package for the Social Sciences software was used to analyze the results statistically.

Conclusion: On analysis, significant differences existed in the shape, length, number, and direction among the populations. However, unification of rugae was not found to be significant statistically.

Keywords: Age, Dental identification, Ethnicity, Forensic odontology, Gender, Palatal rugae.

INTRODUCTION

Forensic science refers "to a group of scientific disciplines which are applied of their particular scientific area of expertise to law enforcement, criminal, civil, legal and judicial matters."

Dr. Edmond Locard, the father of modern forensics, formulated the fundamental principle of forensic science, "Every contact leaves a trace."[1] Forensic odontology deals with teeth and forensic stomatology deals with oral structures other than teeth.

Forensic odontology has three key applications:
1. Diagnosis, therapeutic assessments, and evaluation of injuries to dentition, jaws, and soft tissues of the oral cavity;
2. The person's identification, particularly, in criminal inquiries and/or mass catastrophes; and
3. Identification, analysis, and evaluation of bite marks that are seen in child abuse, sexual assaults, and in personal defense.[2]

Identification comprises a group of procedures to help individualize a person or a substance. However, identity cannot always be conclusively established by one particular method. Forensic dentistry or forensic odontostomatology is that "branch of forensic medicine which in the interest of justice deals with the proper handling and examination of evidence obtained from dental and oral structures and with the proper evaluation and presentation of those findings."

Forensic dentistry has become an integral part of forensic medicine over the past 100 years. The rationale behind forensic odontology is that "no two mouths are alike."[1] Assessment of rugae patterns come under the stomatology part of forensic odonto-stomatology. Palatal rugae refer to "the ridges on the anterior part of the palatal mucosa, each side of the median palatal raphe and behind the incisive papilla."

The rugae patterns are distinctive and individualistic, which can be used in identity fixation. The rugae have been associated with fingerprints and likewise display total individuality. Rugae are confined from injuries by their internal location in the oral cavity, and they are shielded from high temperature by the tongue and the buccal fat pads.

Even between twins, the patterns are analogous, but not identical.[2] Rugae patterns vary among different populations.[3,4] Variations can also be observed with increase in age.[3] Significant differences in rugal patterns can be seen between males and females.[5,6] Even though a number of

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research activities have been done on rugoscopy, only a small number of them have been performed on the Kerala population.

This study is an effort to explore rugoscopy in a study population comprising patients of Kerala ethnicity reporting to the Government Dental College, Kottayam, India. Furthermore, the palatal rugae patterns are compared among different age groups to asses any significant differences with respect to age, sex, and ethnicity, as these aspects could prove to be a valuable step and an adjuvant toward the identification of an individual.

MATERIALS AND METHODS

The study population was recruited between January 1, 2015 and June 31, 2016. The study groups with Kerala ethnicity were divided into five age groups as group I (11–20 years), group II (21–30 years), group III (31–40 years), group IV (41–50 years), and group V (51 years and above). Each group contained 40 samples, i.e., 20 males and 20 females using convenient sampling.

Twelve non-Keralites were available during the study period, who were above 11 years of age, and were taken as the control group. Patients with physical and mental disabilities, serious illnesses, especially posted for major surgeries, having cleft palate and cleft lip, those wearing prosthesis covering the rugae area, and those in which palatal rugae could not be assessed properly were excluded.

Length, direction, shape, unification, and number of rugae were assessed with respect to age, sex, and ethnicity. After ethical clearance from the Institutional Ethics Committee, informed consent was obtained from the patients in case of adults and assent was obtained in the children of the 11 to 15 age group.

Procedure

Alginate impressions of the maxillary arch were made, and casts were preserved for interpretation. The outline of rugae was marked out using 0.5 mm fine lead pencil. The rugae patterns were examined based on direction, shape, length, number, and unification.[2,7] Data for the right and left sides were analyzed separately. The casts procured were segregated into five groups, based on the age of patients and analyzed.

Shape Analysis

The palatine rugae shapes were assessed based on classification by Trobo.[2] Here, the rugae patterns are divided into two types: (1) Simple rugae, classified as Types A, B, C, D, E, and F with well-defined rugae shapes (Fig. 1) and (2) composite rugae, categorized as type X, with a

Classification	Rugae type	Shape
Type A	Point	●
Type B	Line	/
Type C	Curve	⌒
Type D	Angle	⌁
Type E	Sinnous	∫
Type F	Circle	○

Fig. 1: Trobo's classification for determining palatal rugae shape

polymorphism variety (these rugae are formed by the blending of two or more simple rugae). We have included a special type (not specified), NS, in the classification to sort out the rugae that cannot be included in any of above types.

Size Analysis

The size of each rugae was calculated using a digital Vernier caliper, and classified as primary, secondary, and fragmentary according to Lysell.[2] The straight rugae were calculated for the largest longitudinal length, while the circular, curved, sinuous, and angle shapes were calculated by splitting the rugae at each curvature and then summing up the length at each curvature to make up the total length of rugae.

Number Analysis

The number of rugae was counted on the left and right sides separately for each person. The rugae sized less than 2 mm were not taken for the size and number analysis.

Analysis of Direction of the Rugae

The direction of the rugae was assessed by calculating the angle from the line joining its origin to the termination and the line perpendicular to the median rugae. Forwardly directed rugae were associated with positive angles, backwardly directed rugae were associated with negative angles, and perpendicular rugae were associated with zero angles.

Analysis of Unification of Rugae

The fusion of rugae takes place when two rugae are connected at their origin or termination. Rugae were considered splitting, if two rugae had the same origin, but immediately branched out.

Rugae with diverse origins, which are connected sideways, were considered converging. After obtaining the impression, each cast was allotted a serial number, and it was identifiable by that number alone, so that information relating to age, sex, and ethnicity was not known to the observer at the time of measurement. The data collected were transferred to the Excel sheet for statistical analysis.

RESULTS AND DISCUSSION

Until date, the study of palatal rugae has not been extensive, and, hence, palatoscopy can be said to be in its infancy still in the field of forensic odontology. Thomas and Kotze have emphasized on the hurdles in examining, classifying, and interpreting the boundless and minuscule variations in palatal rugae and highlighted the requirement for standardizing the methods for recording them.

In this study, palatal rugae obtained from 224 individuals (100 Keralite males, 100 Keralite females, 12 non-Keralite males, and 12 non-Keralite females) were analyzed.

Variations in Rugae Shape with respect to Age, Sex, and Ethnicity

The rugae shape is better suited for identification than the rugae length.[4] Sinuous (type E) palatal rugae shape is documented as the most prevalent, while the circular (type F) is the least prevalent rugae shape.[8]

However, our results show angular (type D) as the most prevalent shape and linear (type B) as the least prevalent shape (Graph 1). Rugae shapes were not similar on either sides and between the genders in the present study. On comparing each rugae shape among the different age groups and between males and females, highly significant variations ($p < 0.05$) were found in our study.

Change in the shape of at least one rugae, with advancing age in all individuals, has already been documented.[3]

These findings suggest that different age groups in the Kerala subjects show differences in palatal rugae shapes, and this aspect could be helpful toward assessing the age of an unidentified individual after validation studies.

A statistically significant sex variance in the frequency of curved and straight rugae has already been reported among the Indians of Manipal, with a greater occurrence in females than in males.[9] A higher incidence of the wavy rugae among the males has also been reported in the same study. In our population, the angular patterns showed the highest frequencies in both genders.

A definite ethnic correlation could be noted in the rugae patterns in our study as well as other studies. Most of the Keralite subjects in the present study showed the angular pattern, while the non-Keralite population showed curved, sinuous, and angular shapes in equal frequencies. In the Bengaluru population, it was found that the curve form was the most common, suggesting their application in population differentiation.[10] The most common patterns in Australian aborigines and Caucasians were the wavy and the curved forms.[3] They reported a statistically significant relationship between the rugae patterns and ethnicity, with the straight pattern being more frequent in Caucasians, while the wavy pattern was more frequent in aborigines. The wavy pattern was the predominant rugae form in Nepalese subjects.[11] In our study, a statistically significant ($p < 0.05$) difference was found to exist on the left side (Graph 2). The reason for this significance could not be elucidated.

Variations in Rugae Length with respect to Age, Sex, and Ethnicity

The prevalent rugae lengths with respect to age, sex, and ethnicity are given in Tables 1 to 3. Rugae length increases with age in both genders.[12,13] The fact that the maximum
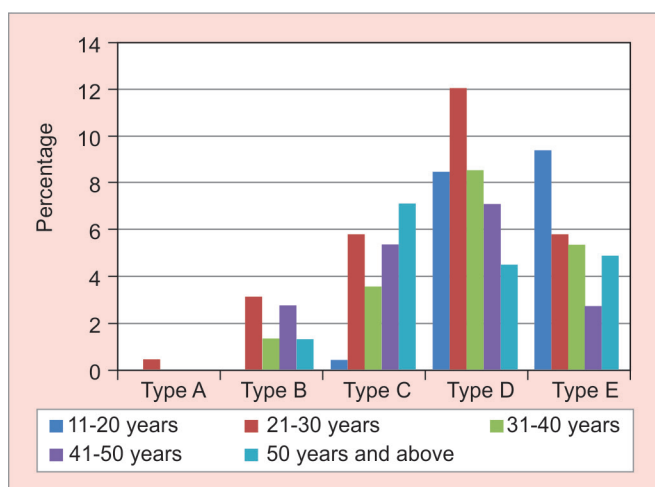
Graph 1: Distribution of different rugae shapes on the left side of the palate in the different age groups
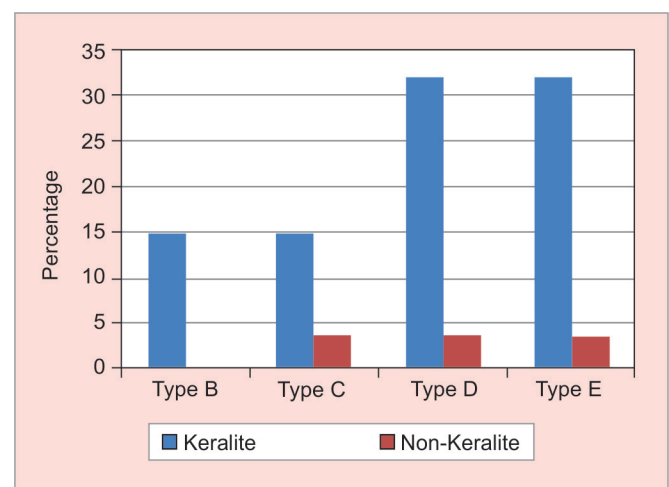
Graph 2: Distribution of different rugae shapes on the left side of the palate in Keralites and non-Keralites

Table 1: Significance of rugae length with respect to age

		n	Mean	Standard deviation	Standard error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Rugae length—right (in millimeters)	11–20 years	41	8.6573	1.20237	0.18778	8.2778	9.0368	5.50	10.40
	21–30 years	61	9.2557	1.90723	0.24420	8.7673	9.7442	5.40	13.70
	31–40 years	42	10.5643	3.09073	0.47691	9.6011	11.5274	5.40	16.30
	41–50 years	40	10.1300	2.28240	0.36088	9.4001	10.8599	5.60	14.30
	50 years and above	40	10.6200	1.70237	0.26917	10.0756	11.1644	6.30	13.60
	Total	224	9.7913	2.23235	0.14916	9.4974	10.0852	5.40	16.30
Rugae length—left (in millimeters)	11–20 years	41	8.229	2.1279	0.3323	7.558	8.901	5.3	12.5
	21–30 years	61	9.480	1.9378	0.2481	8.984	9.977	5.5	14.7
	31–40 years	42	9.426	1.9496	0.3008	8.819	10.034	5.9	13.0
	41–50 years	40	10.338	1.9757	0.3124	9.706	10.969	5.6	14.5
	50 years and above	40	9.695	1.6372	0.2589	9.171	10.219	6.2	13.3
	Total	224	9.433	2.0246	0.1353	9.166	9.699	5.3	14.7

Table 2: Significance of rugae length with respect to gender

		n	Mean	Standard deviation	Standard error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Rugae length—right (in millimeters)	Male	112	9.8500	2.24964	0.21257	9.4288	10.2712	5.40	15.20
	Female	112	9.7326	2.22347	0.21010	9.3163	10.1489	5.60	16.30
	Total	224	9.7913	2.23235	0.14916	9.4974	10.0852	5.40	16.30
Rugae length—left (in millimeters)	Male	112	9.703	2.1780	0.2058	9.295	10.110	5.3	14.7
	Female	112	9.162	1.8287	0.1728	8.820	9.505	5.5	13.3
	Total	224	9.433	2.0246	0.1353	9.166	9.699	5.3	14.7

Table 3: Significance of rugae length with respect to ethnicity

|		n	Mean	Standard deviation	Standard error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Rugae length—right (in millimeters)	Keralite	200	10.0383	2.19417	0.15515	9.7323	10.3442	5.40	16.30
	Non-Keralite	24	7.7333	1.30872	0.26714	7.1807	8.2860	5.40	9.60
	Total	224	9.7913	2.23235	0.14916	9.4974	10.0852	5.40	16.30
Rugae length—left (in millimeters)	Keralite	200	9.597	2.0076	0.1420	9.317	9.876	5.3	14.7
	Non-Keralite	24	8.067	1.6402	0.3348	7.374	8.759	5.5	10.5
	Total	224	9.433	2.0246	0.1353	9.166	9.699	5.3	14.7

dimension of rugae in males and females was observed in the 41 to 50 age group (11.65 ± 1.41 mm) and in the 31 to 40 age group (11.2 mm) respectively, in our study, supports this view.

Once rugae development is complete, the probable alteration in palatal rugae takes place with respect to their length only. Their position remains the same throughout the life of an individual.[13] In our study, bilateral symmetry in rugae length does not exist in both genders. A significant variance was found in our study on the left aspect of the palate, with respect to rugae length in both genders. However, a similar difference was lacking on the right side.

The maximum length of the rugae on the left side was observed in the 41 to 50 age group (10.33 mm) and the minimum length in the 11 to 20 age group (8.22 mm). The maximum length of rugae in Keralites and non-Keralites was 10.34 and 8.75 mm respectively. On comparing the mean rugae length between males and females, a significant difference existed ($p < 0.05$) on the left side, while no significant difference was found on the right side.

A significant difference was noted between Keralites and non-Keralites ($p < 0.05$) on comparing the mean rugae lengths on the right and left sides.

The mean rugae lengths on the right and left sides among all age groups were also found to be significant
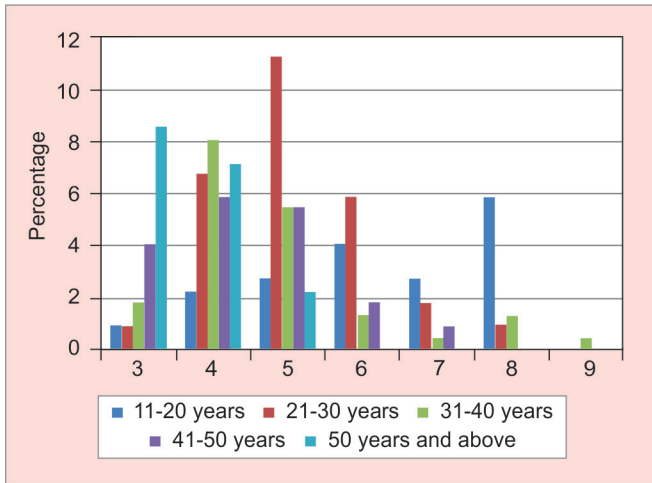
Graph 3: Distribution of rugae number on the left side of the palate in different age groups
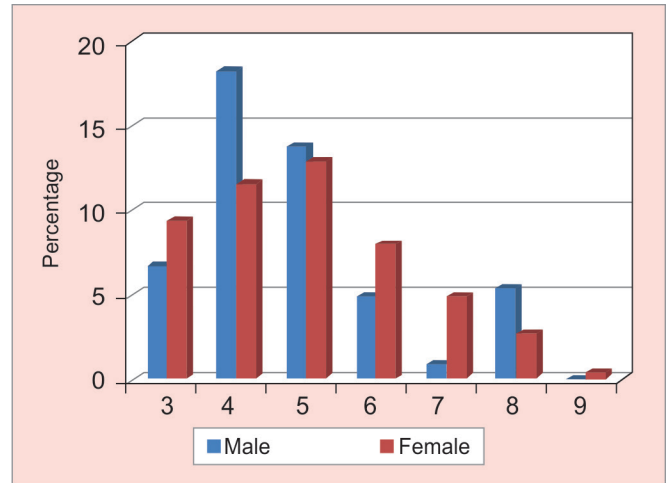
Graph 4: Distribution of rugae number on the left side of the palate in males and females

($p < 0.05$). We could not actually find the significance of rugae length on the left side.

## Variations in Rugae Number with respect to Age, Sex, and Ethnicity

Rugae remain fairly stable in number except when there is trauma (loss of teeth or persistent pressure, which may modify the alignment) or at advanced age.[14] Contrary to this finding, our results show the maximum number of rugae in the 11-to-20 age group on both sides.

A highly significant ($p < 0.05$) difference existed in the prevalence of number of rugae among all the studied age groups (Graph 3). So, we safely hypothesize that a difference in rugae number occurs with age. Rugae count between both genders has been reported to be insignificant in many studies.[6,15,16] In contrast, the number of palatal rugae in the our study revealed a statistically significant difference ($p < 0.05$) between both genders in the Kerala population, with a higher incidence in females (Graph 4).

A similar difference in the number of rugae between both genders was reported in Tibetan and Mysorean populations.[17] But, in contrast to our results, the rugae number was greater in males in the study. No significant difference existed in the number of rugae between Keralites and non-Keralites.

Variations in Rugae Direction with respect to Age, Sex, and Ethnicity

In our study, the most common direction of rugae on the right side was observed to be backward (8.9%) in the 11 to 20 age group, perpendicular (10.7%) in the 21 to 30 age group, forward (10.3%) in the 31 to 40 age group, forward (8.9%) in the 41 to 50 age group, and perpendicular (9.4%) in the 51 years and above age group.
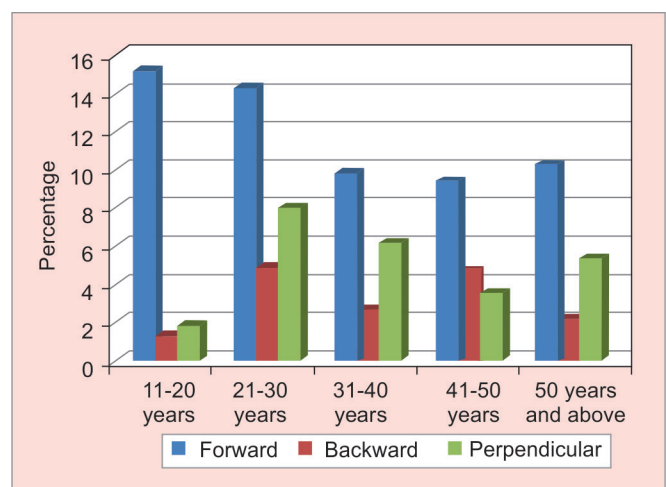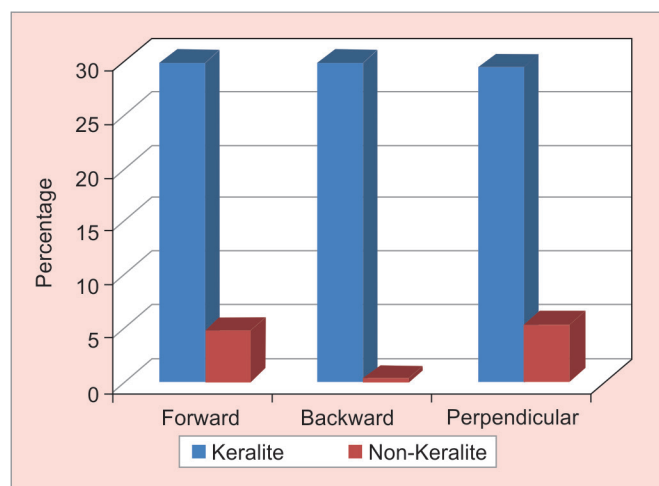

Graph 5: Distribution of rugae direction on the left side of the palate in different age groups

The most prevalent direction of rugae on the left side was found to be forward in all the age groups. The prevalence of direction of rugae among all the study age groups showed significant ($p < 0.05$) difference (Graph 5). But, on comparing the prevalence of direction of rugae between males and females, no significant difference was observed. Similarly, significant results ($p < 0.05$) were seen in the direction of rugae between Keralite and non-Keralite population (Graph 6).

The most prevalent direction of rugae on the right side was forward (29.9%) and backward (29.9%) in Keralites and perpendicular (5.4%) in non-Keralites. The most prevalent direction of rugae on the left side was forward (54.5%) in Keralites and perpendicular (5.4%) in non-Keralites.

Variations in Rugae Unification with respect to Age, Sex, and Ethnicity

No significant disparity was found in rugae unification patterns with respect to age, sex, and ethnicity.

Graph 6: Distribution of rugae direction on the right side of the palate in Keralites and non-Keralites

This was in concurrence with the findings made by Swetha[18] but in contrast to observations made on Saudi females, who had more converging rugae than males.[19] The Trobo classification system, which is used for palatal rugae analysis in this study, exhibits some drawbacks in relation to detailing and accuracy. Most of the previous studies used the Thomas and Kotze classification and, hence, the results of those studies are not comparable with our study.

The rugae direction and unification variables have not been used in the Trobo classification. Hence, we found the assessments of rugae direction and unification difficult. Since, direction and unification of each and every rugae is different in a study cast, we took only the most frequent type of direction and most frequent type of unification into consideration. More studies on different ethnic groups are required to prove a significance of these variables.

Conversely, it can also be assumed that these two variables are insignificant and cannot be taken into consideration for forensic identification. Though the sample size for Keralite population was adequate to satisfactorily assess the association between each variable used and the age and gender of the study sample, the non-Keralite sample size was not sufficient as compared with the Keralite sample size and could have resulted in a bias.

Significant changes were noticeable on the left side. However, further validation studies are required to understand its relevance. The definite correlation between rugae pattern and ethnicity and gender should be followed up using different ethnicities in a larger sample size. Overall, our study results suggest that analysis of palatal rugae can be a useful tool in the identification of an individual.

CONCLUSION

In this study, the variables, such as rugae shape, length, number, direction, and unification were assessed with respect to age, sex, and ethnicity. Among these, rugae shape, length, and number show significant association both statistically and nonstatistically. Though the association of rugae direction and unification with age, sex, and ethnicity was statistically significant, some amount of difficulty was experienced in their assessment. Hence, more studies have to be done on different ethnic groups and on a larger sample size to prove the same.

Conversely, it could also be assumed that these two variables, rugae direction and unification, are insignificant and cannot be taken into consideration for forensic identification. However, the uniqueness and overall constancy of palatal rugae imply their application as an adjuvant tool for forensic identification in different groups. The importance of palatine rugae is highlighted by the fact that chemical injuries, trauma, and decomposition in victims of severe burns cannot affect the rugae forms, and the rugae can also be used for paternity tests.

It would be beneficial to conduct further studies with larger samples for palatal rugae analysis in all of the different ethnic groups of the Indian population. Computer-assisted techniques of assessment will provide accurate results, which will prove to be a common method of analysis of palatal rugae in the near future.

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