Original Article

Palatal rugae pattern: An aid for sex identification

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Abstract

Background: Palatal rugoscopy, or palatoscopy, is the process by which human identification can be obtained by inspecting the transverse palatal rugae inside the mouth. **Aim:** The aim of the study is to investigate the potential of using palatal rugae as an aid for sex identification in Bengaluru population. **Materials and Methods:** One hundred plaster casts equally distributed between males and females belonging to age range of 4–16 years were examined for different rugae patterns. Thomas and Kotze classification was adopted for identification of these rugae patterns. **Statistical Analysis:** The data obtained were subjected to discriminant function analysis to determine the applicability of palatal rugae pattern as an aid for sex identification. **Results:** Difference in unification patterns among males and females was found to be statistically significant. No significant difference was found between males and females in terms of number of rugae. Overall, wavy and curvy were the most predominant type of rugae seen. Discriminant function analysis enabled sex identification with an accuracy of 80%. **Conclusion:** This preliminary study undertaken showed the existence of a distinct pattern of distribution of palatal rugae between males and females of Bengaluru population. This study opens scope for further research with a larger sample size to establish palatal rugae as a valuable tool for sex identification for forensic purposes.

Key words: Discriminant function analysis, forensic odontology, palatal rugae, sex identification

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Introduction

Violence and nature instigated tragedies take away millions of lives often. One of the most challenging situations in forensics is mass disasters where one comes across severely decomposed and fragmented bodies. Through the specialty of forensic odontology, dentists play a small but significant role in identification of victims of crime and disaster through dental records.[1]

The primary and most reliable means of identification are fingerprint analysis, comparative dental analysis, and DNA analysis.[2] However, visual identification and use of fingerprints are limited by postmortem changes associated with time, temperature, and humidity.[3] Even though teeth are said to be more durable than other parts of the body, identification through dental records also may prove to be inconclusive in case dental treatment has been performed between the creation of a dental record and the person's death, if there is loss of any tooth during the mass disaster,

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and also if the victim was edentulous. Although DNA profiling is accurate, it is expensive and time-consuming for use in large populations.[4]

Palatal rugae possess features of an ideal forensic parameter - uniqueness, postmortem resistance, and stability. Moreover, their anatomical positioning inside the mouth keeps them well protected from trauma and high temperatures. Along with these benefits, the use of palatal rugae as a forensic aid has added advantages because of their low utilization cost, simplicity, and reliability.[5]

Thus, the aim of our study was to investigate the potential of using palatal rugae pattern as an aid for sex identification in Bengaluru population.

The objectives were:

1. To identify palatal rugae patterns (in terms of number and shape) in males and females
2. To compare the palatal rugae patterns in males and females
3. To analyze whether palatal rugae pattern can be used as a tool for sex identification.

Materials and Methods

4–16-year-old healthy children of Indian origin residing in Bengaluru, who reported to the outpatient Department of Pedodontics and Preventive Dentistry, Faculty of Dental Sciences, M.S. Ramaiah University of Applied Sciences, Bengaluru, were chosen for the study. Children with congenital anomalies and medically compromised conditions were excluded from the study. The study sample consisted of 100 casts equally distributed between males and females.

Two investigators were involved in the study. The first investigator made the impressions and poured the casts. The second investigator (Chief investigator) was blinded for the study group. Rugae patterns on every cast were delineated using a sharp graphite pencil under adequate light and magnification and classified according to the Thomas and Kotze's Classification [Figure 1].[6] Continuous variables such as rugae length are not suited for forensic purposes because of their dynamic nature.[7] Hence, only shape and unification patterns were made a part of our study.

Results and Discussion

Total number of rugae isolated

A total of 756 rugae were found in the 100 individuals. Out of these, 401 (53.04%) were found in males and 355 (46.96%) in females [Figure 2]. Even though the number of rugae in males was greater than that found in females, it was not statistically significant ($P = 0.08$). Similar results have been reported in the studies done by Kamala *et al*.[1]

Specific pattern-wise distribution of rugae

In the total 756 rugae found, 249 (32.9%) were wavy type. Wavy pattern was found to be the most predominant type. 242 (32%) curvy type of rugae followed by 182 (24.1%) straight rugae were isolated. Unification convergent and divergent types were found in relatively lesser number 45 (6.0%) and 37 (4.9%), respectively. In our study conducted on Bengaluru population, only one circular ruga was isolated [Figure 3].

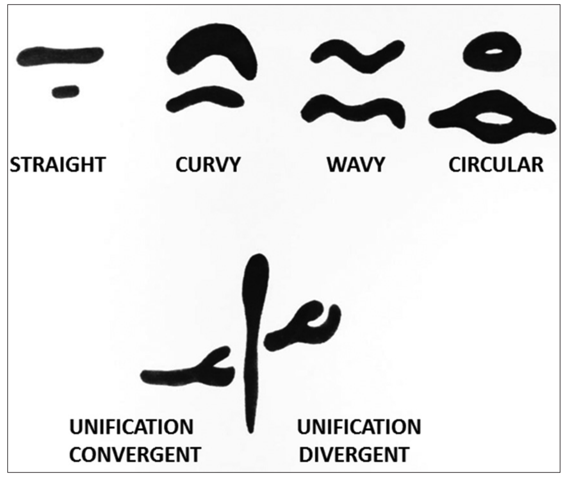

Figure 1: Thomas and Kotze classification of rugae pattern (1983)

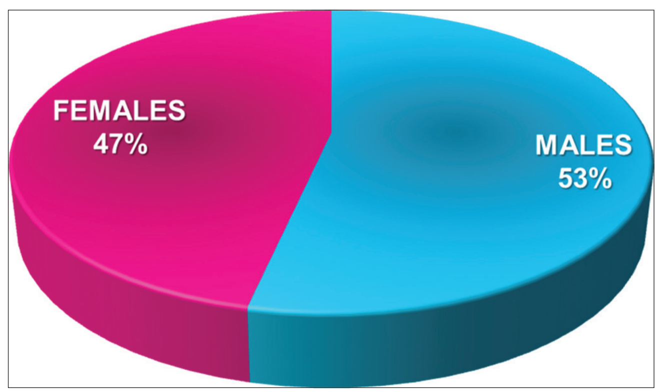

Figure 2: Gender-wise distribution of total rugae isolated

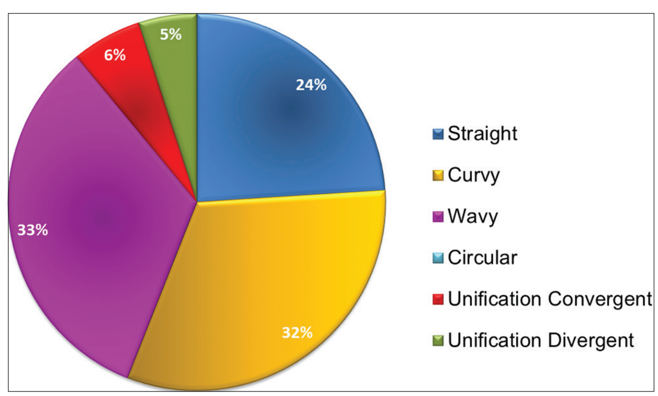

Figure 3: Specific pattern-wise distribution of rugae

Similar results have been reported by Nayak *et al*.,[7] Surekha *et al*.,[8] and Kumar *et al*.[9] in various Indian populations. In the study conducted by Surekha *et al*. on Manipur and Kerala populations, wavy pattern followed by curvy and straight was the most predominant type of rugae. Nayak *et al*. have evaluated the ability of palatal rugae to distinguish between two geographically distinct populations of Karnataka and Gujarat in India and have also found wavy and curvy patterns to be the most predominant types. In another study conducted by Selvamani *et al*.,[10] wavy pattern predominated in both males and females, followed by curve, straight, divergent, convergent, and circular pattern. Furthermore, in the study by Savita *et al*.,[11] curved, straight, and wavy rugae patterns were found to be the most common rugae patterns in both Kerala and Karnataka populations. Our sample from the Bengaluru population belongs to the state of Karnataka and is closely related to the neighboring populations of Kerala and Pondicherry; hence, the similarity of results is justified.

Gender-wise distribution of specific rugae patterns

In males, wavy pattern was the most predominant type (62%) while in females, it was curvy rugae pattern (54%). However, differences between males and females for curvy, wavy, and straight rugae pattern were found to be statistically insignificant.

Females had significantly higher proportion of unification convergent type of rugae as compared to males. On the other hand, males had significantly higher number of unification divergent type of rugae in comparison to females ($P < 0.001$) [Table 1 and Figure 4].

Out of the 756 rugae, only one circular ruga was isolated in our sample population.

Our study is in agreement with the results conducted by Bharath *et al*.[12] on coastal Andhra population, wherein they have tested palatal rugae for sex determination. It was seen that difference in unification patterns among males and females was found to be statistically significant. In another study conducted by Nallamilli *et al*.,[13] the shape of rugae exhibited highly significant sex difference. However, contrary to the results of our study, the curved type was found to be higher in males and wavy type in females in this study. On the contrary, Thabitha *et al*.[14] have found that wavy and curved patterns were the most prevalent in both male and female children but with no significant difference and unification divergent type was significantly more in males than in females.

Out of 50 female casts, two belonged to a pair of twins. A unique observation that we made was, when compared, their rugae patterns were completely non identical [Figure 5]. Thus, it can be said that rugae patterns are unique to individuals irrespective of their genetic makeup. However, we acknowledge that only one pair of twins was studied and that does not allow us to make such a comprehensive statement. However, this finding was consistent with the results quoted by Indira *et al*.[15] where the palatal rugae pattern among five pairs of twins (nonidentical) showed different patterns. Although some are similar, nonidentical forms were observed at specific locations for two twins.

Discriminant function analysis

The data obtained were subjected to discriminant function analysis. Discriminant function analysis is used to determine which variables discriminate between two naturally occurring groups and for classifying cases into different groups with a better than mere chance accuracy.

Table 1 shows the rugae shape that contributed to the discriminant function analysis. Four rugae shapes, such as

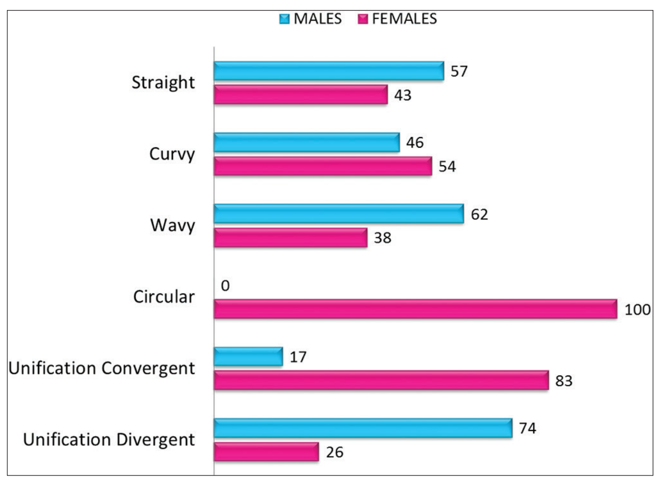

Figure 4: Gender-wise distribution of specific rugae patterns`

Table 1: Step-wise discriminant function analysis of different rugae shape[a,b,c]

Step	Entered	Wilk's lambda							
		Statistic	df1	df2	df3	Exact *F*			
						Statistic	df1	df2	Significance
1	Wavy	0.810	1	1	98.00	23.022	1	98.00	0.000
2	Unification divergent	0.706	2	1	98.00	20.234	2	97.00	0.000
3	Unification convergent	0.654	3	1	98.00	16.928	3	96.00	0.000
4	Straight	0.622	4	1	98.00	14.417	4	95.00	0.000

At each step, the variable that minimizes the overall Wilk's lambda is entered. [a]Maximum number of steps is 10, [b]Minimum partial *F* to enter is 3.84, [c]Maximum partial *F* to remove is 2.71

wavy, unification divergent, unification convergent, and straight, were selected in ten steps in the mentioned order. Wavy entered the analysis first indicating that they have the greatest capability to distinguish between the genders in Bengaluru population.

Tables 2 and 3 depict the unstandardized and standardized coefficients, structure matrix, group centroids, and sectioning point for the discriminant function. The following function was derived with the four most predominant rugae types - straight, wavy, unification convergent, and unification divergent:

GENDER* = 0.292 (straight) + 0.540 (wavy) – 0.616 (unification convergent) + 1.185 (unification divergent) – 2.072

*Specific for Bengaluru population.

To determine the sex of the unidentified individual, the number of each type of rugae shape is multiplied with the respective unstandardized coefficient and added to the constant. If the value obtained is greater than the sectioning point, the cast is said to belong to a male; if the value obtained is less than the sectioning point, the cast is said to belong to a female.

Consider an example to get a better understanding of the complexity of discriminant function analysis. Supposedly, the cast shown in Figure 6 needs to be identified whether it belongs to a male or a female. Considering the cast belongs to an individual from Bengaluru population, the following steps need to be undertaken to determine the sex.

- STEP I: Identification of rugae patterns present
  2 straight rugae; 2 curvy rugae; 2 wavy rugae; 1 unification convergent; 1 unification divergent
- STEP II: Application of the discriminant function already known for the population
  GENDER = 0.292 (straight) + 0.540 (wavy) − 0.616 (unification convergent) + 1.185 (unification divergent) − 2.072
  = 0.292 (2) + 0.540 (2) − 0.616 (1) + 1.185 (1) − 2.072
  = +0.161.
- STEP III: Comparison of the value obtained with the known group centroids
  +0.161 is greater than the sectioning point and closer to the male centroid [Figure 7].
- STEP IV: Interpretation
  The cast can be said to be belong to a male.

The results obtained in our study indicate the expected accuracy of identifying an individual of each sex using the function. This function was subjected to "cross-

Table 2: Canonical discriminant function coefficients

	Function/1
Straight	0.292
Wavy	0.540
Unification convergent	−0.616
Unification divergent	1.185
Constant	−2.072

Table 3: Functions at group centroids

Sex	Function 1
Male	0.771
Female	−0.771

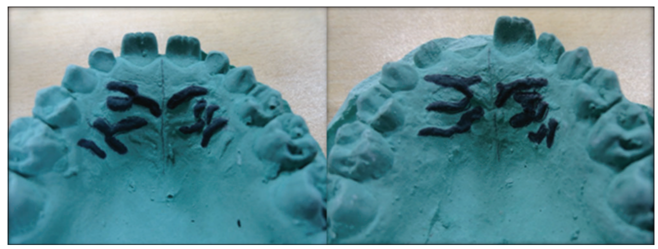

Figure 5: Palatal rugae pattern in a pair of twins

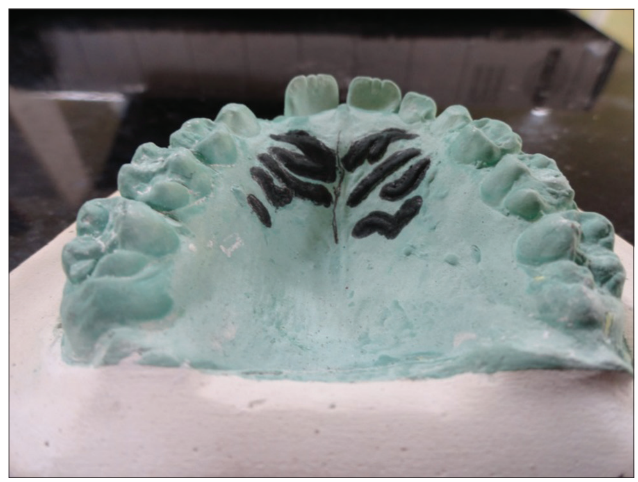

Figure 6: Sample cast used as an example to understand the application of the discriminant function deduced for Bengaluru population

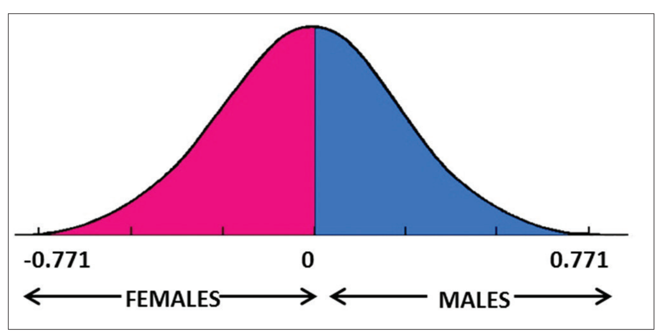

Figure 7: Comparison of the value obtained with the known group centroids

validation" (also called "leave-one-out" cross-validation or "jackknifing"). It is a technique for assessing how accurately the results of a statistical analysis or tool will generalize to an independent data set. Here, a function is derived from all but one cast in the sample and the excluded cast tested for sex identification. When tested, the function gave a jackknife accuracy of 80%.

Conclusion

A distinct pattern of distribution of palatal rugae was seen among males and females of Bangalore population. Within the limitations of the present study, it may be concluded that the rugae pattern may be a method of sex prediction in Bengaluru population. The preliminary study makes way for further studies with a larger sample size and wider age groups to establish palatal rugae as a definite tool for identification in forensic cases.

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Conflicts of interest

There are no conflicts of interest.

References

1. Kamala R, Gupta N, Bansal A, Sinha A. Palatal rugae pattern as an aid for personal identification: A forensic study. J Indian Acad Oral Med Radiol 2011;23:173-8.
2. Disaster Victim Identification Guide. In: DVI Guide: INTERPOL; 2009. Available from: http://www.interpol.int/Public/DisasterVictim/guide/guide.pdf. [Last accessed on 2017 Mar 17].
3. Morlang WM. Forensic dentistry. Aviat Space Environ Med 1982;53:27-34.
4. Sweet D, DiZinno JA. Personal identification through dental evidence-tooth fragments to DNA. J Cal Dent Assoc 1996;24:35-42.
5. Jain A, Chowdhary R. Palatal rugae and their role in forensic odontology. J Invest Clin Dent 2014;5:171-8.
6. Thomas CJ, Kotze TJ. The palatal ruga pattern: A new classification. J Dent Assoc S Afr 1983;38:153-76.
7. Nayak P, Acharya AB, Padmini AT, Kaveri H. Differences in the palatal rugae shape in two populations of India. Arch Oral Biol 2007;52:977-82.
8. Surekha R, Anila K, Reddy VS, Hunasgi S, Ravikumar S, Ramesh N. Assessment of palatal rugae patterns in Manipuri and Kerala population. J Forensic Dent Sci 2012;4:93-6.
9. Kumar S, Vezhavendhan N, Shanthi V, Balaji N, Sumathi MK, Vendhan P. Palatal rugoscopy among Puducherry population. J Contemp Dent Pract 2012;13:401-4.
10. Selvamani M, Hosallimath S, Madhushankari PS, Yamunadevi A. Dimensional and morphological analysis of various rugae patterns in Kerala (South India) sample population: A cross-sectional study. J Nat Sci Biol Med 2015;6:306-9.
11. Savita JK, Yathindra Kumar BN, Satish G, Divya KT, Ranjitha J, Pujari RK. Prevalence of palatal rugae shapes in Karnataka and Kerala population: A cross-sectional study. J Int Soc Prev Community Dent 2016;6:230-3.
12. Bharath ST, Kumar GR, Dhanapal R, Saraswathi T. Sex determination by discriminant function analysis of palatal rugae from a population of coastal Andhra. J Forensic Dent Sci 2011;3:58-62.
13. Nallamilli SM, Tatapudi R, Reddy SR, Chennoju SK, Kotha R, Kotha P. Diversity of palatal rugae patterns and their reliability in sex discrimination in a South Indian population. J Indian Acad Oral Med Radiol 2015;27(1):9-12.
14. Thabitha RS, Reddy RE, Manjula M, Sreelakshmi N, Rajesh A, Kumar VL. Evaluation of palatal rugae pattern in establishing identification and sex determination in Nalgonda children. J Forensic Dent Sci 2015;7:232-7.
15. Indira A, Gupta M, David MP. Usefullness of palatal rugae patterns in establishing identity: Preliminary results from Bengaluru city, India. J Forensic Dent Sci 2012;4:2-5.