

## Variations in the Palatal Rugae Patterns in Indian Populations – A Need for a Multi-Centric or Multi-Regional Study under Forensic Context

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### Abstract:

*Palatal rugae are the anatomical mucosal elevations that are seen in the anterior hard palate. Palatal rugae number and their patterns are not uniform in all individuals, they appear to vary in several population subsets. They are associated with variations in different regions of India and can aid as an additional tool in forensic identification procedures. Palatal rugae studies are being reported from different parts of India. It has been observed that qualitative and quantitative variations occur in palatal rugae among several population subsets in India. Variations which are gender based in the palatal rugae have also been reported in the literature. This article reviews the pattern of variations seen in palatal rugae in different geographic locations in India as reported in the scientific literature. It is observed that the population in the Southern part of India has shown dominance in wavy patterns, whereas, in Northern and central India, the straight pattern was more common. Rugae patterns are considered as important anatomic markers in forensic human identification, large-scale multi-centric research is required to validate palatal rugae features in discriminating population (groups) in India. Thus in situations of mass disaster, the soft tissue component like rugae may be an addendum to the dental features in identifying human remains.*

**Keywords:** *Geographical Variations, Palatal Rugae, Population Variation, Rugoscopy, Forensic Human Identification*

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## Introduction

India is a land of diversity known for its variety of cultures, religions, and languages. As we move from north to south and west to east we find differences in ethnicity, secularity, heritage, and experience. Geographical diversity in India is well known across the world. Variations and diversities exist all along with the country. Considering the aspects of dentistry, an anterior third of the hard palate has a significant anatomic landmark, palatal rugae which have noticeable anatomic variations among various geographical population groups (Byatnal *et al.*, 2014).

Palatal rugae are defined as irregular and non-identical mucosal elevations that are seen on the anterior one-third of the palate. They run in a transverse direction on either side of the mid palatine raphe (Banker *et al.*, 2016). They are protected by lips, a buccal pad of fat, and teeth (Nanci, 2003). The number and patterns of palatal rugae vary in all individuals and also in various population subsets. 'Palatoscopy or Rugoscopy term is used for studying palatal rugae which were first proposed by Trobo Hermosa, a Spanish investigator.

The rugae patterns are relatively unique in an individual and are known to be stable throughout the lifetime after the completion of growth. They retain their anatomic details even in the burn victims and during taphonomic decompositions to a certain extent (Muthusubramanian *et al.*, 2005). Thus, they can be used for successful post-mortem identification provided there is a pre-existing antemortem record. In orthodontic treatments, the position of the rugae changes after the maxillary expansion, while the shape and number remain unchanged (Shailaja *et al.*, 2018). However, the stability of the palatal rugae during and after that orthodontic treatment remains a topic of debate, especially when applied under a forensic context (Deepak *et al.*, 2014). There are several studies done on palatal rugae patterns in the Indian population from different states. The review of the literature in this area is done and after compiling the results from those studies, conclusions have been drawn in this article.

## Classification of the Palatal Rugae

The Palatal rugae classification which is widely accepted was given by Thomas and Kotze in the year 1983. They classified rugae based on unification pattern, length, shape and direction. Individual rugae length is measured transversely from its start point at the mid-palatine raphe to its endpoint. Primary rugae: 5–10 mm, Secondary rugae: 3–5 mm, Fragmentary rugae: <3 mm. According to shape, they are classified as Straight - terminates in the straight line; Curved- has

a crescent shape and a gradual curve; wavy- serpentine shape of rugae; Circular- continuous ring formation. The direction of rugae is seen by the angle formed between a line joining origin and the termination of rugae concerning the mid- palatine raphe. Forward-rugae have positive angles in respect to MPR; Backwards-angles are negative with respect to MPR; Horizontal- if the angle is zero to MPR; Perpendicular- the rugae that run parallel to MPR. The term "Unification" is used when the two rugae join at their origin or insertion. When two rugae begin from the same origin but bifurcate transversely are called Diverging rugae; whereas, converging are the ones in which rugae with different origins joins on their lateral positions (Pillai *et al.*, 2016).

The palatal rugae, in most of the studies, were analyzed using the dental models (Indira *et al.*, 2012).

The application of advanced digital technologies like digital photographs of the models and 3D digital scanning of dental models are also being tried to analyze rugae patterns (Santos *et al.*, 2011; Mohammed *et al.*, 2013; Bavaresco *et al.*, 2020; Taneva *et al.*, 2015).

## Palatal Rugae in the Population Differentiation

Shanmugam *et al.* (2012) have shown that palatal rugae patterns may accurately discriminate the South Indian and North Indian populations in nearly 88% of the cases.

Rath and Reginald (2014) studied the rugae patterns in Andhra Pradesh and Odisha populations. The straight and unspecified patterns were seen to be predominant in the Andhra population, whereas in the Odisha population, the wavy type was common. By stepwise discriminant analysis, they found that the discriminating power of rugae patterns was 93.5% in discriminating the two study populations.

The prevalence of rugae shapes in the Kerala and the Karnataka populations was compared using a cross-section. The study reveals a significantly higher distribution of curved patterns in the Kerala population than seen in the Karnataka population. The study reveal that the discriminating value was significant with the curved and straight patterns only for identifying the population group. Using the chi-square test the palatal rugae patterns percentage were Wavy and Curved-29.4%, straight and circular with 28.5% and 1.5% respectively. Some unification patterns were seen at about 2.4%, divergent patterns were more than around 4% than the convergent. The incidence of different rugae shapes in the population of Karnataka was wavy 22.6%, curved 20.5%, straight - 44.1%,

circular - 0.5% and unification pattern is seen in 6.3% of the samples and divergent patterns were significantly more than the convergent (Savita *et al.*, 2016).

Sureka *et al.* (2012) assessed rugae patterns in Manipuri and Kerala populations. Their study also showed the distribution of curved patterns was significantly different between study populations. The Manipuri population shows more curved patterns than the Kerala population.

The patterns of palatal rugae in Western Indian and Southern India were compared. The study showed that the straight, curved, and wavy patterns contributes to the discrimination of the study populations with an accuracy rate of 70% (Nayak *et al.*, 2007).

Byatnal *et al.* (2014) compared the palatal rugae patterns in 5 states; Andhra Pradesh, Tamil Nadu, Karnataka, Madhya Pradesh, and Maharashtra populations. In their study, the wavy pattern was found to be predominant in all the states. In Madhya Pradesh, the wavy was highly prevalent when compared with the other patterns. The wavy pattern was followed by a straight pattern in all the states except Tamil Nadu. In the Tamil Nadu population, it was followed by a curvy pattern. In Andhra Pradesh, almost 76% of the samples had a wavy pattern, around 14% had straight, followed by 10% with straight. The circular pattern in rugae was not observed in that population. In Madhya Pradesh, wavy patterns accounted for 92% of the total samples and the remaining were straight type. For the state of Karnataka, the wavy pattern accounted for 80%, 18% for straight and curved patterns were seen in only 2% of the samples. In Maharashtra, 64% of the rugae showed a wavy pattern, 12% showed straight and only 6% accounted for curved types. In Tamil Nadu, 68% showed wavy followed by 24% curved and 12% were straight.

Another comparative study reported a straight pattern as dominant in the Madhya Pradesh population which is followed by the straight and curvy patterns. In the same study, the Keralite population showed a predominance of the wavy pattern followed by curves and then by straight patterns (Paliwal *et al.*, 2010).

In a study in the Gujarat population, the rugae patterns showed a predominance of straight patterns which followed by the curved, wavy, and circular in the decreasing order approximating to percentages of 41.2%, 3.7%, 19.2%, and 0.9%. There are no significantly observed variations found among the opposite sexes. Out of all the samples selected, 36.4% were of the horizontal rugae which were followed by forward (33%) and backward (29.2%). Only 1% of

those showed perpendicular patterns. From the selected samples divergent types of unification patterns were more common than the convergent type (Pillai *et al.*, 2016).

Shanmugam *et al.* (2012) compared the rugae patterns in populations of North and South India. A sample size of 974 was selected with South and North population groups ranging from 18-23 years of age. This study used the Chi-square test and also aimed at developing the discriminant formula by a stepwise discriminant functional analysis. Towards the north wavy and curved were the maximum, followed by the straight with not much of a significant difference. In the southern population, wavy predominated followed by curved and straight. This study didn't specify a particular state in the north and south. It included samples from educational institutes and colleges from the north and south India. The discriminant function analysis of the different rugae shapes in this study can distinguish the southern Indian population from the Northern one with a classification accuracy of nearly 88%. Another study by Rai and Anand showed that the Northern Indian population had a predominance of the straight pattern.

In North India, we found a study involving the Punjabi population as the target sample reports that straight patterns were significantly common in north India along with the primary form which is followed by a curved and secondary form of rugae (Kaur *et al.*, 2021).

For the South, another study mainly considering the populations of Kerala wavy patterns predominated followed by the curved and straight. It mentions the occurrence of circular patterns more in males than females (Selvamani *et al.*, 2015).

A study from Chennai, in Southern India aimed at sex determination through palatal rugae patterns, which also shows that wavy pattern was more common in both males and females, followed by curved. Straight and circular patterns were found in very fewer proportions both in males and females (Anjum, 2018).

Again there is some contrast with the conclusions drawn from studies in similar regions, especially in Northern India. Even though there are similarities the ratios vary. While analyzing the shape of the palatal rugae in a Bengali population in Murshidabad carried on by Ashutosh *et al.*, it was observed that the predominant shape of rugae was curved followed by wavy, straight, and circular shapes. The study doesn't specify any age groups. Also amongst all the studies, we find significant gender variations in the patterns in this particular study. There are a higher number of

rugae in females than the male, especially on the right. There were no significant differences when the total number of the rugae patterns were compared between genders. Even in the rugae patterns, the number of females exhibiting curved rugae are significantly more than the ones in male. Also, while comparing the directions of rugae the backward directing rugae in females were significantly and perpendicular was common in males. No difference was seen in the unification patterns (Pramanik, 2019).

All these studies dealt with the objectives of evaluating and comparing rugae patterns in the selected sample. Some of them also analyzed and compared patterns based on size, number, shape, direction, and unification, considering either one or more of these parameters. What we could infer is that palatal rugae patterns vary among different population groups. Generally, it was observed that there is a predominance of straight patterns in northern India, whereas in the South wavy pattern is common. Along with the states on the west coast, we found variations in rugae patterns from one state to another. Towards the east, wavy was found to be common. We could infer that these studies were carried out on a very smaller scale about the actual population size of that state. For concluding accurately more such tests need to be carried out on a larger scale to deduce a precise hypothesis. In the referred articles that were compared the age groups were not specified or not similar for the two studies. No two studies had the same amount of samples and they were randomly selected from various population subsets. Not all the studies had a homogenized statistical analyzing method.

The fact underlined in these studies can conclude that the palatal rugae patterns vary from population to population. Thus there is a scope of discriminating the populations based on the palatal rugae patterns.

### Conclusion and Future Recommendations

The present review article is just an attempt to report the findings of existing literature on rugae patterns in Indian populations from several states. What is required, is a standardized way of sample selection with a multicentric approach on a larger sample size from each centre. This mandates a need for the team of researchers to exclusively study the rugae patterns in the Indian population and to generate a 'Rugae Profile' of the Indian population. This further will hold a great significance of palatal rugae in the process of human identification and forensics. The palatoscopy or Rugoscopy gained importance in recent times in the field of forensics because it could be applied where no fingerprints are available. It can be applied in the cases of decomposed and burnt bodies and also in cases where important parts like the forelimbs are missing, where fingerprint identification will not be possible. The method is fast, simple, inexpensive, and produces no trauma during recordings. Rugae patterns can be analysed rapidly using a standardized procedure. Hence, the multi-centric/ multi-regional standardized studies on a larger scale will provide a paradigm shift for research in forensic odontology.



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