NO-FEE OPEN ACCESS JOURNAL indexed in Scopus

Bulletin of the International Association for Paleodontology

Volume 19, Issue 1, 2025

Established: 2007

CONTENT

Reviewers of this issue:

Aspalilah Alias, David Bulbeck, Aman Chowdhry, Andrea Cucina, Jannick Detobel, Lorenzo Franceschetti, Laura Gonzalez-Garrido, Rakesh Gorea, Tamas Hajdu, HebaIbrahim Lashin, Matthew James Lee, Senad Muhasilović, Masniari Novita, Oskar Nowak, Amir Abdul Rahim, Rabi'ah Al-Adawiyah binti Rahmat, Kasia Sarna Bos, Ricardo H.A. Silva, Ana Maria Silva, Parul Sinha, Nurtami Soedarsono, Marlin Tolla, Leticia Vilela Santos, Selma Zukic.

We thank all the reviewers for their effort and time invested to improve the papers published in this journal.

Palatal rugae pattern and tongue print as a potential tool for gender identification in forensic odontology: a cross-sectional study*

• Prajakta Khelkar (1), Ayushi P Mangulkar (2), Bharathi S (3), Sanpreet Singh Sachdev (4), Freny R Karjodkar (5), Aswathi Unnikrishnan (5) •

1 - Department Of Dentistry, Government Medical College and Hospital, Chandrapur
2 - Department Of Dentistry, Government Medical College & JJ college of Hospitals, Mumbai
3 - Department Of Oral Medicine and Radiology, Government Medical College and Hospital, Aurangabad
4 - Department of Oral Pathology and Microbiology, Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Navi Mumbai
5 - Department of Oral Medicine and Radiology, Nair Hospital Dental College, Mumbai

Address for correspondence:
Sanpreet Singh Sachdev
317, Department of Oral Pathology, Bharati Vidyapeeth (Deemed to be University) Dental College and Hospital, Sector 7, Belapur CBD, Navi Mumbai – 400614, India
Email: sunpreetss@yahoo.in

Bull Int Assoc Paleodont. 2025;19(1):33-41.

Abstract

Palatal rugae and tongue morphology have been widely studied for their potential applications in forensic identification and anthropology. Their uniqueness and stability make them valuable markers for gender differentiation. This study aimed to analyse the palatal rugae and tongue morphology in a selected population and assess their applicability in gender identification. A total of 200 participants (100 males and 100 females) were enrolled in this observational study. Palatal rugae were recorded using maxillary casts and classified based on number, shape, length, direction, and unification. Tongue morphology was assessed using standardized photographs, focusing on shape, border, and fissures. Statistical analysis was conducted to determine gender-based differences. The mean number of total palatal rugae was significantly higher in males (9.13 ± 2.08) compared to females (8.47 ± 1.86, $p<0.05$). Males exhibited a greater number of straight rugae, while wavy and curved patterns were prevalent in both genders. The most common tongue shape was U-shaped (55%), followed by V-shaped (36.5%) and bifid (8.5%), with significant gender differences ($p<0.05$). Smooth tongue borders were more frequent in females, whereas scalloped borders were more prevalent in males. The study highlights significant gender differences in palatal rugae patterns and tongue morphology, supporting their utility in forensic identification. These findings reinforce the importance of oral anatomical structures as adjunctive tools in forensic and anthropological studies. Further research incorporating digital analysis techniques may enhance identification accuracy.

Keywords: palatal rugae, tongue morphology; gender identification; forensic science; anthropology

Introduction

Forensic odontology has emerged as an indispensable field in forensic science, contributing significantly to the identification of individuals based on dental and oral structures (1). The ability to identify a person, whether living or deceased, is fundamental for various legal, social, and humanitarian reasons. Dental records have long served as a reliable means of forensic identification due to the resilience of dental structures to adverse environmental conditions such as fire, trauma, and decomposition (2). While conventional forensic techniques such as fingerprint analysis, lip prints, DNA profiling, and dental identification remain widely utilized, emerging methods such as palatal rugae pattern analysis and tongue prints offer promising avenues for personal identification, particularly in cases where traditional methods are inadequate. Palatal rugae, irregular transverse ridges on the anterior third of the hard palate, have been established as a stable and unique anatomical landmark useful in forensic investigations (3). These structures develop during the early intrauterine life, remain largely unchanged throughout a person's lifetime, and exhibit significant individual variability, making them a viable parameter for personal identification (4). The stability of palatal rugae, coupled with their resistance to post-mortem changes, has led to their increasing acceptance in forensic odontology (5). Numerous studies have demonstrated the presence of sexual dimorphism in palatal rugae patterns, further strengthening their applicability in gender determination. Studies by Bhardwaj et al. (2024) and Bhatnagar et al. (2024) have highlighted the variations in palatal rugae patterns among different populations, emphasizing their role in ethnicity and gender differentiation (6,7).

Similarly, tongue prints have recently gained attention as a novel biometric tool in forensic science (8). The tongue is a highly protected organ, enclosed within the oral cavity, and remains well-preserved even under extreme conditions. It possesses unique morphological features, including shape, texture, and fissure patterns, which differ from person to person, making it a reliable method for personal identification (9). Unlike fingerprints, which may be altered due to wear and environmental exposure, tongue prints remain largely unaltered, offering a secure and tamper-resistant biometric identifier. Studies by Kulig et al. (2024) and Johnson et al. (2018) have demonstrated the potential of tongue morphology in forensic identification, supporting its use as an emerging biometric tool (10,11). Emerging forensic research highlights the sexual dimorphism of tongue characteristics, suggesting that tongue morphology could serve as a crucial parameter for gender determination in forensic investigations (12,13).

Despite the promising potential of palatal rugae and tongue prints in forensic odontology, research remains limited regarding their comparative efficacy in gender identification.13 Understanding the predominant patterns of palatal rugae and tongue morphology in different populations can enhance their forensic applicability and provide additional tools for law enforcement agencies in human identification cases. The present study aimed to assess the number, pattern, and predominant characteristics of palatal rugae and tongue prints in a sample population of Mumbai while analysing their role in gender identification.

Materials and Methods:

Study Design and Data Collection

This prospective observational study was conducted over a period of two years from October 2019 to October 2021. The study protocol adhered to the STROBE guidelines and was approved by the institutional ethical review board. A total of 200 patients, comprising 100 males and 100 females, visiting the Oral Medicine department of the hospital were enrolled in the study based on predefined inclusion and exclusion criteria. The study population included healthy individuals within the age range of 13 to 60 years. Subjects with preexisting palatal and tongue disorders, congenital anomalies affecting the palate and tongue, bony and soft tissue protuberances, areas of active lesions and scars, as well as systemic illnesses were excluded from the study. A detailed case history was recorded, and a clinical examination was performed following thorough rinsing of the oral cavity. After obtaining informed consent, palatal rugae casts were made, and photographs of the dorsal surface of the tongue were taken.

Sample Size Calculation

A convenient sampling technique was employed for the selection of participants. The sample size was determined using the expected proportion of outcomes in each group, with values estimated from existing literature. The calculation followed the formula:

$n = (Z\alpha + Z\beta)2\ (p(1-p) + q(1-q)) / (p-q)2,$

where Zα represents the z variate of alpha error (1.96), Zβ represents the constant for beta error (0.84), and p and q denote the proportions of the variables based on prior studies. Based on an estimated power of 80%, a type I error rate of 5%, and a type II error rate of 20%, with an expected outcome proportion of 75% and 55%, the sample size for each group was calculated to be approximately 85. To enhance external validity, the sample size was rounded to a minimum of 100 subjects in each category, yielding a total of 200 participants.

Palatal Rugae Analysis

The palatal rugae pattern was recorded by taking impressions of the maxillary arch using alginate powder, followed by the fabrication of dental casts with dental stone. The materials utilized included alginate powder, perforated metal maxillary impression trays, mixing bowls, spatulas, dental stones, and water. The rugae, appearing as elevated impressions on the casts, were marked with a black permanent marker for enhanced visualization. The classification of rugae patterns was performed based on length, shape, direction, and unification, following the criteria established by Lysell, Thomas, and Kotze similar to a previous study by Rajan et al. (2013) (14).

The total number of rugae, number of primary rugae, predominant shape, predominant direction, and pattern of unification were assessed. Rugae length was measured using a slide caliper under magnification to an accuracy of 0.05 mm. Rugae were categorized into primary (>5 mm), secondary (3 to 5 mm), and fragmentary (<3 mm), with rugae measuring less than 2 mm disregarded. The shape of the rugae was classified as curved, wavy, straight, or circular based on their contour and alignment (Figure 1). The direction of rugae was determined by measuring the angle formed between the line connecting its origin and termination with the line perpendicular to the median raphe. Based on the measured angles, rugae were classified as forwardly directed, backwardly directed, or perpendicular. Unification of rugae was noted when two rugae merged at either their origin or termination, and these were further classified as diverging (same origin but branching laterally) or converging (different origins merging at the lateral portion).

All maxillary dental casts were meticulously examined, and the recorded data were subjected to statistical analysis to assess the prevalence and distribution of different rugae patterns among the study population.

Tongue Morphology Analysis

Prior to the clinical examination, patients were instructed to rinse their mouths with water to remove any debris or food particles. Subjects were asked to protrude their tongues in a relaxed position to prevent contraction of the striated lingual muscles, ensuring clear visibility of the dorsal surface. Standardized photographs were obtained using a DSLR camera (Canon 3000) under controlled lighting conditions and from a predetermined distance to maintain consistency in imaging. The digital photographs were used to analyse various parameters, including tongue shape, border characteristics, and fissure patterns. The frontal view of the tongue was used to classify its shape, while the assessment of borders and fissures was based on detailed observation of the images.

The shape of the tongue was categorized as U-shaped, V-shaped, or bifid (Figure 2). The border characteristics were classified as smooth, partially scalloped, or scalloped (Figure 3). The tongue fissures were identified based on their presence or absence, with further classification into single or multiple fissures (Figure 4). The collected data were systematically analysed to identify trends and variations in tongue morphology within the study population.

Statistical Analysis

The collected data from the palatal rugae casts and tongue morphology assessment were compiled in Microsoft Excel and subjected to statistical analysis using SPSS software. The association between rugae patterns and gender was analysed using an independent t-test. The prevalence of various tongue morphology aspects with respect to gender was evaluated using the chi-square test. Frequency and percentage distributions of different morphological characteristics were compared across the study population, and a significance level of $p<0.05$ was considered statistically significant.

Results

The mean age of the study participants was 34.75 ± 11.03 years, with a minimum age of 18 years and a maximum of 67 years. The gender distribution was equal, with 100 males and 100 females, and no statistically significant difference was observed between them ($p>0.05$).

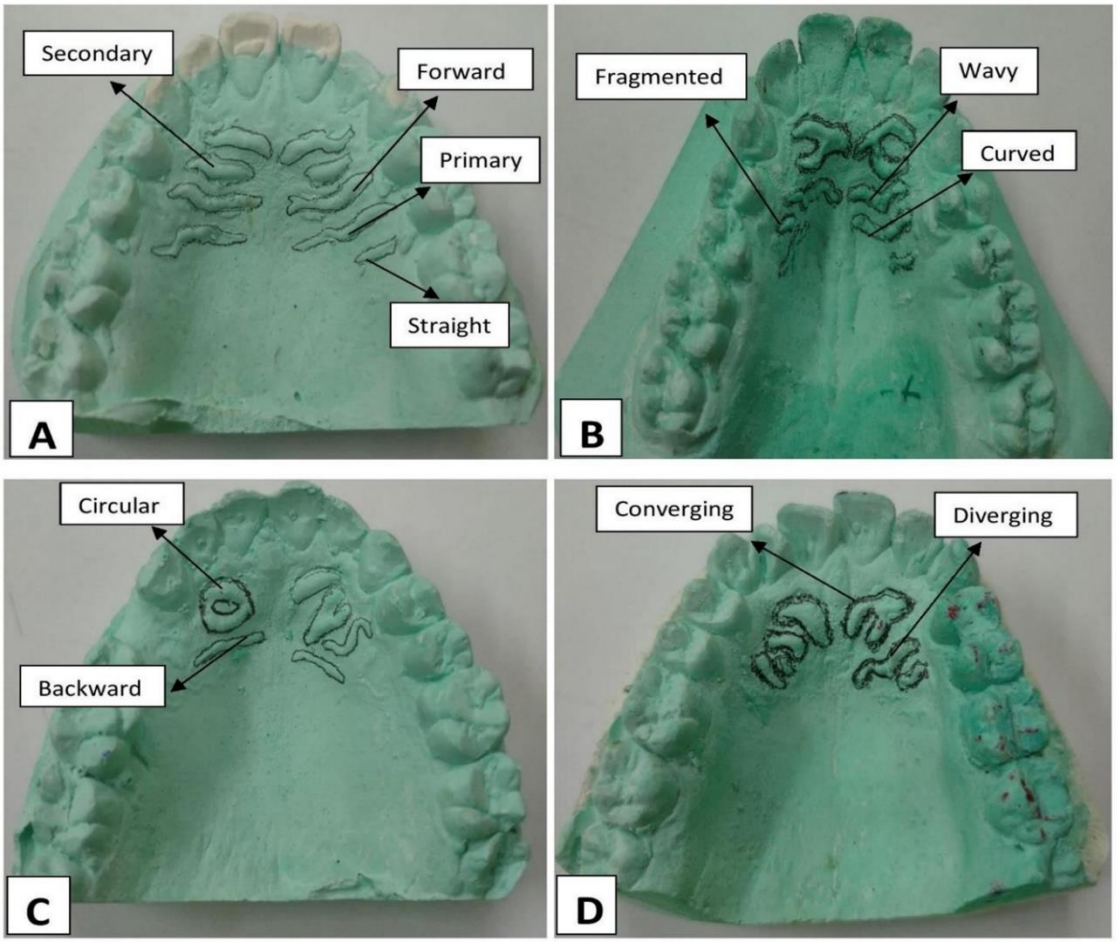

Figure 1. Maxillary casts showing various rugae patterns.

Figure 2. Shape of the tongue categorized as A) U-shaped, B) V-shaped, and C) Bifid.

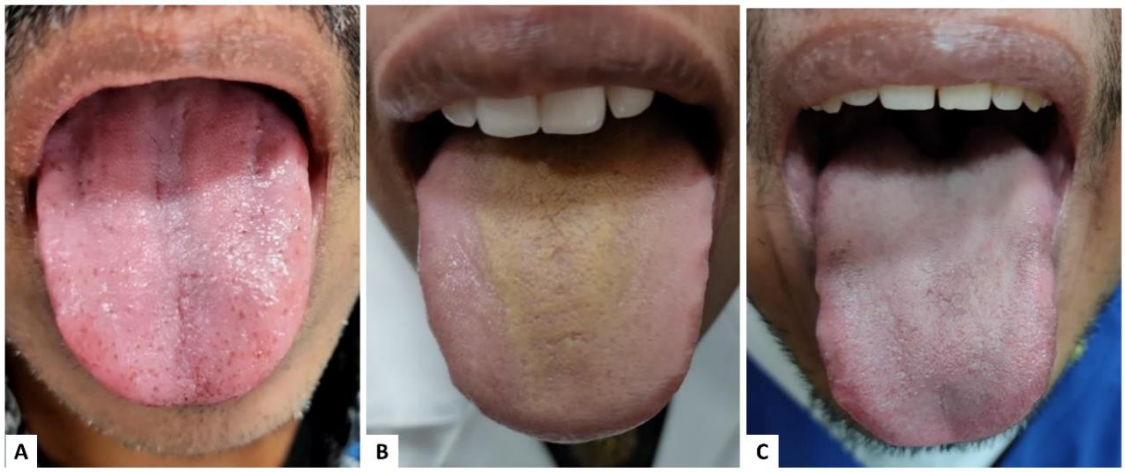

Figure 3. Borders of tongue categorized as A) smooth, B) partially scalloped, and C) scalloped.

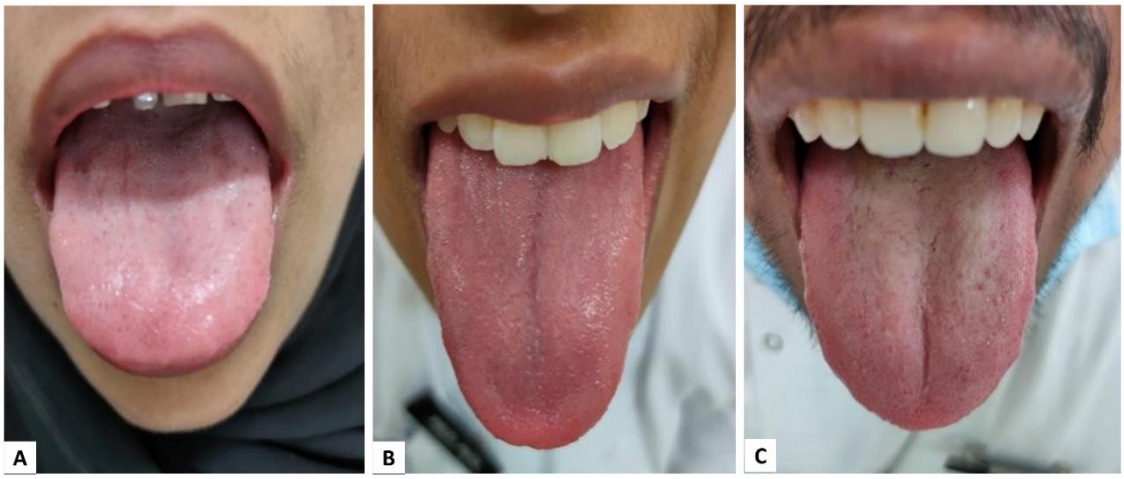

Figure 4. Fissures of the tongue categorized as A) absence of fissure, B) single fissure, and C) multiple fissures.

Palatal Rugae Analysis

The mean total number of palatal rugae was significantly higher in males (9.13 ± 2.08) compared to females (8.47 ± 1.86), with a mean difference of 0.66 ($p<0.05$). Primary and secondary rugae lengths were also higher in males, with statistical significance noted for secondary rugae ($p<0.05$). Fragmented rugae did not show a significant difference between genders (Table 1).

When assessing the shape of palatal rugae (Table 2), straight rugae were significantly more frequent in males (2.04 ± 1.21) compared to females (1.50 ± 1.26, $p<0.05$). Wavy and curved rugae were comparable between genders, while circular rugae showed no significant difference. The directional patterns of palatal rugae, including forward, backward, and perpendicular orientations, did not exhibit significant gender differences ($p>0.05$). The unification patterns of rugae, whether diverging or converging, were also similar between males and females.

Tongue Morphology Analysis

U-shaped tongues were the most common, found in 55% of participants, followed by V-shaped (36.5%) and bifid tongues (8.5%). A significant difference in tongue shape was observed between genders ($p<0.05$). The prevalence of smooth tongue borders was significantly higher in females (47%) compared to males (37%), whereas scalloped borders were more frequent in males (9.5%) than females (1.0%) ($p<0.05$). Tongue fissures were predominantly absent in both genders, and no significant difference was noted between males and females regarding multiple or single fissures ($p>0.05$). The results related to tongue morphology analysis are collectively summarized in Table 3.

The results indicate that gender differences in palatal rugae and tongue morphology are statistically significant for certain parameters, particularly in rugae number, shape, and tongue border characteristics. However, directional patterns of rugae and tongue fissure prevalence did not exhibit significant gender differences

Table 1. Gender-based comparison of quantitative rugae analysis

Gender	Mean Total Rugae	Primary Rugae	Secondary Rugae	Fragmented Rugae	P-Value
Male	9.13 ± 2.08	4.85 ± 1.30	2.70 ± 1.09	1.58 ± 1.24	<0.05*
Female	8.47 ± 1.86	4.49 ± 1.29	2.57 ± 0.97	1.49 ± 1.26	

Table 2. Gender-based comparison of rugae patterns

Gender	Straight	Wavy	Curved	Circular	Backward	Forward	Perpendicular	P-Value
Male	2.04 ± 1.21	4.21 ± 1.64	1.88 ± 1.30	0.29 ± 0.49	3.47 ± 1.29	5.13 ± 1.86	0.45 ± 0.64	<0.05*
Female	1.50 ± 1.26	3.93 ± 1.29	2.07 ± 1.20	0.42 ± 0.63	3.13 ± 1.20	4.87 ± 1.85	0.47 ± 0.76	

Table 3. Gender-based comparison of tongue morphology

	Shape			Border			Fissures			
Gender	U-Shape (%)	V-Shape (%)	Bifid (%)	Smooth Border (%)	Partially Scalloped (%)	Scalloped (%)	Absent Fissure (%)	Multiple Fissures (%)	Single Fissure (%)	P-Value
Male	28.5	15.5	6.0	37.0	3.5	9.5	42.0	3.0	5.0	<0.05*
Female	26.5	21.0	2.5	47.0	2.0	1.0	40.0	3.0	7.0	

Discussion

The present study aimed to assess the palatal rugae pattern and tongue morphology for gender identification. The findings demonstrated significant differences in certain aspects of rugae shape, number, and tongue morphology between males and females. These observations align with previous research and reinforce the potential role of these oral structures in forensic identification and anthropological studies.

The present study found that males had a significantly higher mean number of total rugae compared to females, with a notable difference in the number of primary and secondary rugae, particularly in the secondary rugae category. This finding aligns with the results of Hermosilla et al. (2009), who reported a greater number of rugae in males than females, highlighting sexual dimorphism in rugae patterns (15). Similarly, Rajan et al. (2013) also found increased primary rugae counts in females, supporting our observation of gender-based variation (13).

The predominant shape of palatal rugae in our study was the wavy pattern, followed by curved and straight forms, while circular rugae were the least common. These findings are consistent with earlier studies by Chong et al. (2020) and Bajracharya et al. (2013), which observed wavy as the most frequent rugae pattern across various populations (4,16). However, the present study also showed a significant difference in the occurrence of straight rugae, which were more prevalent in males, corroborating findings by Prakoeswa et al. (2024) who find a similar pattern in the Javanese population of Indonesia (17). In contrast, Saxena et al. (2017) reported straight rugae to be common in females in an Indian population sample (18).

Regarding the directional classification of rugae, the present study did not find significant gender differences in the forward, backward, or perpendicular orientation of rugae. This result is in contrast to studies by Saxena et al. (2015) and Gandikota et al. (2012), which reported distinct directional preferences in different population groups (19,20). The lack of significant variation in our study may be attributed to sample composition, genetic factors, or environmental influences that affect rugae formation.

Unification patterns, including diverging and converging rugae, showed no statistically significant gender differences, which is in agreement with findings by Mutalik et al. (2013) and Oberoi et al. (2016), indicating that unification is a less reliable marker for gender differentiation (21,22). Our results showed that U-

shaped tongues were the most common among both males and females, followed by V-shaped and bifid tongues. The findings are consistent with those of Kulig et al. (2024) and Venkatesh et al. (2019), who also reported U-shape as the predominant tongue form (10,23). However, a significant gender difference was observed in tongue shape, with V-shaped tongues more common in females, which aligns with previous findings by Jeddy et al. (2017) and Sreepradha and David (2019) (1,25).

Tongue border analysis revealed that smooth borders were significantly more prevalent in females, while scalloped borders were observed more frequently in males. This finding is supported by Johnson et al. (2018), who also noted a higher incidence of scalloped borders in males (11). The presence of multiple fissures was more common in males, whereas single fissures were slightly more frequent in females. However, this difference was not statistically significant, in agreement with the observations of Vijay et al. (2019) and Panchbhai and Parida (2022), who found similar trends but with limited significance (26,27).

The findings of this study support the use of palatal rugae and tongue morphology as adjunctive tools in forensic identification. The relatively stable nature of rugae patterns throughout life, as observed by Rojas-Torres et al. (2025), enhances their forensic applicability (28). Additionally, studies by Gaikwad et al. (2019) and Hosmani et al. (2018) emphasized that rugae analysis can provide population-specific and gender-related information, supporting our findings (29,30).

Tongue morphology has also been proposed as a biometric identifier due to its unique patterns and stability over time. As noted by Gehi (2021), tongue shape, texture, and fissure patterns can serve as distinguishing characteristics in forensic dentistry (31). The findings of the present study reinforce this concept by highlighting significant gender differences in tongue border characteristics, which may be useful in personal identification.

Although our study provides valuable insights into the gender-based variations in the lingual and rugae morphology of the population of Mumbai, certain limitations must be considered. The study sample was limited to a specific population, and genetic or environmental influences on rugae and tongue patterns were not extensively analysed. Future studies with larger, more diverse populations could provide a broader understanding of these patterns across different ethnicities and geographical regions. Further research is also needed to integrate digital analysis techniques, such as 3D scanning and artificial intelligence-based pattern recognition, to enhance the accuracy and reliability of rugae and tongue morphology analysis in forensic applications.

Conclusion

The present study demonstrated significant gender differences in palatal rugae number, shape, and tongue morphology, reinforcing their potential role in forensic and anthropological identification. While palatal rugae exhibited sexual dimorphism in terms of total number and shape, tongue morphology revealed gender-specific variations in shape and border characteristics. Tongue prints, including variations in shape, fissures, and border morphology, have shown promise as a forensic tool due to their uniqueness and stability over time. These findings contribute to the growing body of evidence supporting the use of these anatomical structures as reliable tools in forensic science, particularly for sex determination and personal identification.

Declaration of Interest

None

Author Contributions

PK, AM, BS, SS, FK, and AU contributed to the conceptualization and methodology of the study. PK, AM, BS, and SS were involved in investigation, data collection, and original draft preparation. AM, AU, BS, and SS contributed to data curation, formal analysis, and visualization. PK, BS, SS, and AU participated in the literature review and validation of findings. FK, AM, and SS provided critical revision, supervision, and overall guidance throughout the project. FK and AU contributed to final editing and approval of the manuscript. All authors (PK, AM, BS, SS, FK, and AU) have read and approved the final manuscript and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Statement on the use of artificial intelligence in manuscript preparation

Artificial intelligence was not used in the preparation of this manuscript.

References

1. Jeddy N, Ravi S, Radhika T. Current trends in forensic odontology. J Forensic Dent Sci. 2017 Sep;9(3):115-9.
2. Salazar AM, Huerta PA, Coliboro-Dannich V, Castro AF, Barbaro A. Evaluation of DNA in human teeth—ante-mortem and post-mortem factors affecting degradation and preservation: a literature review. Genes. 2025 Mar 22;16(4):364.
3. Tey SN, Syed Mohamed AM, Marizan Nor M. A morphometric approach to morphology analysis of palatal rugae in sibling groups. J Forensic Sci. 2024 Jan;69(1):189-98.
4. Chong JA, Mohamed AM, Pau A. Morphological patterns of the palatal rugae: a review. J Oral Biosci. 2020 Sep;62(3):249-59.
5. Kundu A. Forensic odontology: bridging the gap between dental science and criminal investigation. Int J Ethics Trauma Vict. 2024 Aug 28;10(1):18-27.
6. Bhardwaj I, Lukose S, Siddharth M. Determination and categorization of the variations in the palatal rugae between Indian and Negroid population. J Forensic Med Toxicol. 2024;41(2):136-41.
7. Bhatnagar A, Arya S, Kumar JS, Arya A, Morya KC, Baroopal S. The determination of heritability in palatal rugae pattern among parents and their off-springs in Western India – a cross-sectional study. J Forensic Sci Med. 2024 Jan 1;10(1):42-6.
8. Radhika T, Jeddy N, Nithya S. Tongue prints: a novel biometric and potential forensic tool. J Forensic Dent Sci. 2016 Sep;8(3):117-9.
9. Nimbulkar G, Patil R, Nathani S, Salve S, Chhabra KG, Reche SD. Tongue prints: a forensic review. Indian J Forensic Med Toxicol. 2020 Oct;14(4):6802-7.
10. Kulig K, Wiśniowski M, Thum-Tyzo K, Chałas R. Differences in the morphological structure of the human tongue. Folia Morphol (Warsz). 2024;83(2):262-74.
11. Johnson A, Gandhi B, Joseph SE. A morphological study of tongue and its role in forensic odontology. J Forensic Odontol. 2018 Apr;3(1):3-8.
12. Rana P, Suresh D, Sekhar MC, Sravanthi YM, Mehta KH. Patterns of identity: lip prints, tongue prints and mandibular canine width as markers for gender determination—a cross-sectional study. J Family Med Prim Care. 2024 Oct 1;13(10):4528-33.
13. Malik S, Nayak MT, Goyal M, Sanath AK, Malik U. Determination of sexual dimorphism using tongue prints – a prospective cross-sectional study. Univ J Dent Sci. 2022;8(1):1-6.
14. Rajan VP, John JB, Stalin A, Priya G, Abuthagir AS. Morphology of palatal rugae patterns among 5–15 years old children. J Pharm Bioallied Sci. 2013;5(1):43-7.
15. Hermosilla VV, San Pedro VJ, Cantín IM, Suazo GIC. Palatal rugae: systematic analysis of its shape and dimensions for use in human identification. Int J Morphol. 2009;27(3):819-25.
16. Bajracharya D, Vaidya A, Thapa S, Shrestha S. Palatal rugae pattern in Nepalese subjects. Orthod J Nepal. 2013;3(2):36-9.
17. Prakoeswa BF, Kurniawan A, Nurdiansyach I, Chusida AN, Marini MI, Rizky BN, et al. Exploring sexual dimorphism through palatal rugae analysis in the Javanese population of Surabaya, Indonesia. Eur J Anat. 2024 Nov;28(6):685-90.
18. Saxena V, Deheriya M, Datla A, Bhargava A, Tiwari N, Shoukath S. Palatal rugae characteristics: a comparative analysis among gender identities in Indore, India. J Forensic Dent Sci. 2024 Jan 1;15(1):25-9.
19. Bharath TS, Govind Rajkumar N, Raghu D, Saraswathi TR. Sex determination by discriminant function analysis of palatal rugae from a population of Coastal Andhra. J Forensic Dent Sci. 2011;3(2):58-62.
20. Saxena S, Chandrashekar BR, Hongal S, Torwane N, Goel P, Mishra P. A study of the palatal rugae pattern among male, female, and transgender populations of Bhopal city. J Forensic Dent Sci. 2015;7(2):142-7.
21. Gandikota C, Venkata TP, Challa P, Juvadi SR, Mathur A. Comparative study of palatal rugae pattern in Class II div I and Class I individuals. J Pharm Bioallied Sci. 2012;4(2):358-63.
22. Mutalik VS, Menon A, Jayalakshmi N, Kamath A, Raghu AR. Utility of cheiloscopy, rugoscopy, and dactyloscopy for human identification in a defined cohort. J Forensic Dent Sci. 2013 Jan;5(1):2-6.
23. Oberoi IS, Chalkoo AH, Dhingra K. Evaluation of rugae pattern in individuals of a known population: a population-based study. Int J Appl Dent Sci. 2016;3(1):1-4.
24. Venkatesh SB, Kamath V, Hasbullah NB, Syafiqah N, Mutalib A, et al. A preliminary study of tongue prints for biometric authentication. Int J Comput Sci Netw Secur. 2019;20(12):1-6.
25. Sreepradha C, David MP. Tongue replica for personal identification: a digital photographic study. J Forensic Odontol. 2019;1(1):57-61.
26. Vijay P, Sharma S, Chandra S, Pardhe N, Singh P, Srivastava Y. A study on evaluation of various tongue patterns in North Indian population and a working classification system for these tongue print patterns. J Forensic Sci Res. 2019;2(2):76-9.
27. Panchbhai A, Parida R. Evaluation of human tongue morphology and tongue groove patterns to explore its potential as a forensic aid. Ann RSCB. 2021;25(4):7164-72.

28. Rojas-Torres JA, López-Lázaro S, Viciano J, Fonseca GM. Digital matching of palatal rugae patterns for forensic identification in edentulous denture wearers. Forensic Sci Med Pathol. 2025 Mar;21(1):157-64.
29. Gaikwad R, Kamble S, Rana R, Jain S, Gondivkar S, Bajad P. Rugae patterns as an adjunct to sex differentiation in forensic identification. Stomatologija. 2019;21(2):79-82.
30. Hosmani J, Gadekar NB, Vijayalakshmi S. Comparison of palatal rugae pattern among Indian and Tibetan population. J Forensic Odontol. 2018;1(1):40-4.
31. Gehi S. Study of tongue morphology in Central India population: a budding tool in forensic odontology. J Forensic Sci Res. 2021;6(2):1-6.