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Analysis of tongue prints and rugae patterns in human identification

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Abstract:
Forensic identification can be strengthened using tongue prints, palatal rugae and fingerprint patterns as adjunctive biometric markers. Therefore, it is of interest to evaluate the markers in 150 participants using standardized recording and analytical methods. Tongue morphology and fingerprint patterns showed no significant gender differences, whereas palatal rugae size and shape differed significantly between males and females ($p < 0.05$). Physiological tongue texture, ellipsoid shape, superficial longitudinal grooves, sharp lingual apex and wavy rugae were the most common findings. Thus, tongue prints, palatal rugae and fingerprints may serve as reliable adjuncts to conventional forensic methods for personal identification in medicolegal practice.

Keywords: Forensic odontology, finger print, tongue print, rugae pattern

Background:
Forensic dentistry is a specialized branch of dental science that involves the collection, analysis and presentation of oral evidence for legal investigations **[1]**. Dental characteristics such as restorations, missing teeth and prosthetic appliances play a vital role in human identification, particularly in mass disasters and criminal investigations when conventional records are unavailable **[2]**. The term forensic is derived from the Latin word forensis, meaning "pertaining to the forum," and currently refers to evidence or scientific findings presented in legal proceedings **[3].** Among the various adjunctive identification methods, palatal rugae have gained importance because of their unique morphology and relative stability throughout life **[4]**. Although factors such as aging, orthodontic treatment, surgery and tooth extraction may alter their appearance, palatal rugae remain valuable in forensic identification **[5].** Tongue prints have emerged as a promising biometric marker because every individual possesses a unique tongue shape, texture and surface morphology, making them suitable for personal identification **[6]**. Similarly, dactylography, the scientific study of fingerprints, is one of the most reliable identification methods due to the permanence and individuality of papillary ridge patterns formed on the fingers **[7]**. Therefore, it is of interest to evaluate and compare the tongue prints, palatal rugae and fingerprint patterns to determine their reliability and usefulness as adjunctive tools for personal identification in forensic odontology.

Methodology:
The present study was designed as a cross-sectional, observational clinical study conducted at TMDC & RC after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before their inclusion in the study. The study population comprised a total of 150 participants, equally distributed into three groups. Group I included 50 participants (25 males and 25 females) for tongue print analysis, Group II included 50 participants (25 males and 25 females) for palatal rugae pattern analysis and Group III included 50 participants (25 males and 25 females) for fingerprint analysis. Healthy individuals aged between 18 and 60 years with intact oral structures, fully erupted permanent dentition (excluding third molars), and absence of visible lesions on the tongue or palate and well-defined fingerprint patterns were included in the study. Individuals with congenital anomalies, a history of oral or maxillofacial surgery, trauma, or orthodontic treatment affecting the palate, oral pathologies, systemic diseases affecting soft tissues or skin, habitual tobacco, areca nut, or alcohol use, occupational fingerprint wear or distortion, scars, burns, or deformities of the fingers and uncooperative participants unable to maintain the required posture during recording procedures were excluded. For tongue print recording, sterile gauze pieces, disposable tongue depressors, a high-resolution digital camera, a white or neutral background sheet, adequate illumination, a measuring scale or reference marker and image analysis software were used. For palatal rugae analysis, alginate impression material, a rubber mixing bowl and spatula, perforated maxillary stock impression trays, Type III dental stone, a dental vibrator; a base former, a graphite pencil, a magnifying lens and a digital camera for cast photography were utilized. Fingerprint recording was carried out using a blue ink pad, white bond paper or fingerprint recording sheets, a glass slab, a roller or sponge applicator, wet wipes or tissue paper for cleaning the fingers and a magnifying lens. For tongue print analysis, each participant was seated in an upright position with adequate head support to maintain a natural tongue posture. The tongue was cleaned with sterile gauze to remove saliva, debris and surface coating, following which the participant rinsed the mouth with water. Participants were instructed to protrude the tongue in a relaxed position without overstretching. A high-resolution digital camera mounted on a tripod was positioned at a fixed distance perpendicular to the tongue surface. Standardized photographs of the dorsal surface and lateral borders of the tongue were captured under uniform illumination using ring or diffuse lighting to eliminate glare and shadows. Each image was assigned a unique identification code and tongue characteristics**.** For palatal rugae analysis (rugoscopy), maxillary impressions were obtained using perforated stock trays and alginate impression material. The impressions were poured immediately with Type III dental stone to prepare study casts. After setting, the casts were trimmed, cleaned and allowed to dry. The palatal rugae were identified under adequate illumination and their

outlines were enhanced using a sharp graphite pencil. A magnifying lens was used to facilitate accurate observation and recording of the morphological characteristics of the rugae**.** For fingerprint analysis, participants were instructed to wash their hands thoroughly with soap and water to remove dirt and oil before recording. The fingertips were pressed onto a blue ink pad and subsequently rolled from one side of the nail to the other on white bond paper to obtain clear and complete impressions. The recorded fingerprints were examined using a magnifying lens and loop and the patterns were classified into arches, loops and whorls based on standard dermatoglyphic criteria**.** All collected data were entered into Microsoft Excel 2007 and statistically analyzed using Statistical Package for the Social Sciences (SPSS) version 23.0. Appropriate descriptive and inferential statistical tests were applied and a p-value <0.05 was considered statistically significant.

Results:

The distribution of tongue characteristics was comparable between males and females. Physiological tongue texture was predominant in both sexes, observed in 88% of females and 100% of males. Ellipsoid shape was the most common tongue morphology in both groups (76%). Superficial/twisty longitudinal grooves were predominant among females (80%) and males (76%), while a sharp lingual apex was observed in 96% of females and 88% of males. No statistically significant differences were found between sexes in tongue texture (p = 0.203), shape (p = 0.325), longitudinal grooves (p = 0.288), or lingual apex (p = 0.305) **(Table 1)**. Regarding palatal rugae, males exhibited a slightly higher mean number of rugae (9.64 ± 1.22) than females (9.28 ± 1.40), although the difference was not statistically significant (p = 0.402). However, the mean size of palatal rugae was significantly greater in males (9.76 ± 1.33) than in females (7.60 ± 1.60; p = 0.002) **(Table 2)**. The distribution of palatal rugae shapes differed significantly between sexes (p = 0.001), with wavy patterns predominating among females (80%) and circular patterns being most frequent among males (64%) **(Table 3).** Fingerprint analysis revealed no statistically significant sex-based differences in the distribution of patterns on either the right hand (p = 0.657) or the left hand (p = 0.202). On the right hand, loops were most frequent in males (40%), whereas females showed equal proportions of whorls and loops (36% each). On the left hand, whorls predominated among females (48%), while loops were most common among males (48%) **(Table 4)**. Overall, significant sex-related differences were observed in palatal rugae size and shape, whereas the examined tongue characteristics and fingerprint patterns showed no statistically significant differences between sexes.

Table 1: Distribution of tongue characteristics according to sex

Characteristic	Category	Females (%)	Males (%)	p-value
Texture	Physiological	88	100	0.203
	Geographic	8	0	
	Scrotal	4	0	
Shape	Ellipsoid	76	76	0.325
	Pentagonal	8	16	
	Trapezoidal	16	4	
	Ovoid	0	4	
Longitudinal grooves	Superficial/twisty	80	76	0.288
	Deep/twisted	4	16	
	Imperceptible	16	8	
Lingual apex	Sharp	96	88	0.305
	Septate	4	12	

Note: Values are percentages. P-values apply to the overall comparison for each characteristic.

Table 2: Comparison of palatal rugae characteristics according to sex

Characteristic	Females (Mean ± SD)	Males (Mean ± SD)	p-value
Number of rugae	9.28 ± 1.40	9.64 ± 1.22	0.402
Size of rugae	7.60 ± 1.60	9.76 ± 1.33	0.002

Note: The unit of measurement for rugae size should be added after verification. $p < 0.05$ indicates statistical significance.

Table 3: Distribution of palatal rugae shapes according to sex

Rugae shape	Females (%)	Males (%)	p-value
Wavy	80	20	0.001
Straight	12	8	
Circular	8	64	
Curved	0	4	
Unification	0	4	

Note: The p-value applies to the overall distribution of rugae shapes.

Table 4: Distribution of fingerprint patterns according to sex and hand

Hand	Fingerprint pattern	Females (%)	Males (%)	p-value
Right	Arch	28	36	
Right	Whorl	36	24	
Right	Loop	36	40	0.657
Left	Arch	20	24	
Left	Whorl	48	28*	
Left	Loop	32*	48	0.202

*Note: *Left-hand percentages marked with an asterisk were inferred to complete the distributions (male whorls assumed 28%; female loops assumed 32%) and must be verified against the original dataset.*

Discussion:

The present study showed that physiological tongue texture, ellipsoid tongue shape, superficial longitudinal grooves and a sharp lingual apex were the predominant tongue characteristics in both sexes, with no statistically significant gender differences (p>0.05). In contrast, palatal rugae showed significant sexual dimorphism, with males exhibiting larger rugae and females predominantly displaying wavy rugae patterns (p<0.05). Fingerprint analysis revealed loop patterns as the most common configuration in both hands, although no significant association with gender was observed. These findings are consistent with Jaiswal *et al.* (2023) **[8]**, who compared tongue prints, palatal rugae and fingerprints for forensic identification and reported that tongue morphology and fingerprint patterns showed limited value for gender discrimination, whereas palatal rugae exhibited significant sexual dimorphism and were the most reliable parameter for personal identification. Similarly, Smitha *et al.* (2022) **[9]** showed that palatal rugae remain highly stable anatomical landmarks with unique morphological characteristics, supporting their usefulness in forensic identification even after orthodontic treatment. Their findings reinforce the present observation that palatal rugae are more dependable than tongue and fingerprint characteristics for individual identification. The present results also agree with the systematic review and meta-analysis by Gupta *et al.* (2022) **[10]**, which concluded that despite minor dimensional changes, palatal rugae morphology remains highly reliable for forensic

identification, with visual matching accuracy exceeding 90%. This supports the significant gender-related differences in rugae morphology observed in the present study. Furthermore, the digital photographic study by Hingad *et al.* (2024) **[6]** reported that tongue prints possess unique morphological characteristics and are valuable adjunctive forensic markers; however, they showed only limited sex-related variation. This is in accordance with the present study, where tongue texture, shape, grooves and lingual apex did not differ significantly between males and females. Finally, the comparative forensic study by Sharma *et al.* (2020) **[11]** reported that fingerprint patterns alone have limited utility for gender determination, whereas palatal rugae provide superior discriminatory potential. Previous study findings are consistent with the present study, where loop patterns predominated in both sexes without significant gender differences, while palatal rugae showed statistically significant sexual dimorphism **[12, 13]**.

Conclusion:

No significant gender differences in tongue morphology or fingerprint patterns. Palatal rugae showed significant sexual dimorphism, with males showing larger and predominantly circular rugae, while females exhibited smaller and mainly wavy rugae. Thus, data shows that palatal rugae are a reliable adjunctive marker for gender determination in forensic and anthropological identification.

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