

A Study of Palatal Rugae Pattern in Gender Identification

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Citation

Neupane G, Sapkota B, Rimal U, Shrestha S, Suwal R. A Study of Palatal Rugae Pattern in Gender Identification. *Kathmandu Univ Med J.* 2025; 93(5): 36-41. (Special Issue)

ABSTRACT

Background

Human identification in postmortem scenarios, whether through dental records or other means, remains one of the most challenging tasks in forensic science. Palatoscopy serves as a valuable tool for establishing person's identity. Palatal rugae; possess unique patterns, exhibit stability and demonstrate individuality as well as sexual dimorphism.

Objective

To investigate the potential of using palatal rugae pattern as an aid in sex identification.

Method

This cross sectional study was conducted between August to December 2024 among the patient aged 18 to 40 years visiting department of Prosthodontics, Dhulikhel Hospital. Black marker pen was used to delineate the outline of rugae in maxillary cast obtained from alginate impression. The length of rugae was measured with the help of digital vernier caliper and brass wire. Independent sample T-test and Mann Whitney U tests were used to compare the rugae between genders.

Result

In the present study, a total of 1,050 palatal rugae were traced. Males were found to have a statistically significantly higher number of rugae on left side compared to females (p-value = 0.03). Diverging rugae in males were most predominant type of unification (p-value = 0.018), whereas straight rugae were significantly more common in females than in males (p-value = 0.026). No statistically significant difference was observed in length of palatal rugae between genders.

Conclusion

The study found that no two individuals shared identical palatal rugae patterns. Palatal rugae may serve as a useful tool for gender identification and can be recommended for forensic applications.

KEY WORDS

Gender identification, Palatal rugae, Rugoscopy

INTRODUCTION

Palatal rugae are irregular, asymmetrical mucosal ridges that extend laterally from the incisive papilla and the anterior region of the palatal raphe.¹ Palatal rugae develop around the third month of fetal life from the connective tissue of the palatal process of the maxilla. Each person's rugae pattern is distinct and remains unchanged with growth.² Physiologically, palatal rugae play a role in swallowing, taste perception, speech articulation, and suction in children, and they also serve as an aid in medico-legal identification.³ Palatoscopy, or palatal rugoscopy, is the examination of palatal rugae to determine a person's identity.⁴

Sassouni noted that every individual's palate has a unique configuration that does not change with growth.⁵ Identifying human remains after death is crucial and remains one of the most challenging tasks, whether done through dental or other means.⁶ Even in severe accidents such as plane crashes, fires, or explosions, where fingerprints are destroyed, palatal rugae patterns stay preserved. Once formed, they remain in the same position for life, changing only in length as a person grows.⁷ Because of their unique and stable nature, palatal rugae are highly useful for forensic identification.⁸ The significance of palatal rugae in identification stems from their individual uniqueness.⁹

Although there is no single standard for describing palatal rugae patterns, they are preferred in forensic identification because they are simple, reliable, and inexpensive.¹⁰ This study was conducted because few publications have examined palatal rugae patterns in the Nepalese population. It aims to describe the rugae and explore their relationship with gender.

METHODS

This was a cross-sectional analytical study conducted among the patients age group 18-40 years visiting the Department of Prosthodontics, Dhulikhel Hospital, Kathmandu University School of Medical Sciences (KUSMS) from August 2024 to December 2024. Ethical clearance was obtained from Institutional Review Committee of KUSMS after submission of research proposal (IRC No: 277/24). Sample size was calculated based on difference of means at 95% CI, medium effect size of 0.6, at 90% power and α at 0.05 and taken from the study done by Thabitha et al.⁶ Software used was G Power 3.1. A total of 98 Nepalese subjects comprising of 49 male and 49 female were chosen randomly and were included in the study. Subjects with abnormalities of palate and lips like cleft palate and lip, history of orthodontic treatment, allergic to impression material, bony and soft tissue protuberances, lesions, deformity, scars and trauma were excluded. The study was conducted after obtaining institutional research committee (IRC) approval and informed verbal consent from the subjects. Alginate (Septodont) impressions of maxillary

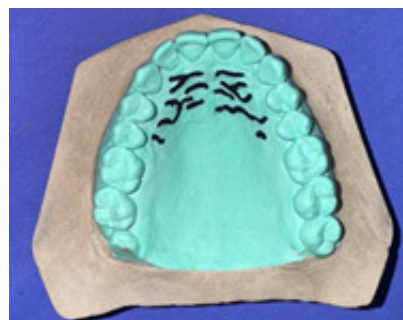


Figure 1. Palatal rugae traced on the dental cast

arch were made in perforated metal impression trays and dental stone casts were made. Black marker pen was used to delineate the outline of palatal rugae (Fig. 1) under adequate light and magnification. Flexible brass wire and Vernier caliper (Mitutoyo) of 0.01 mm accuracy were used to measure the length of rugae. Number, length, shape and unification of the palatal rugae were recorded based on the classification by Thomas and Kotze and Kapali et al.^{11,12} A single examiner performed all identifications and measurements.

Based on length:

Primary: > 5 mm

Secondary: 3-5 mm

Fragmentary: 2-3 mm

Rugae less than 2 mm were not considered for any categorization

Based on shape:

Straight: rugae ran directly from origin to termination

Curved: simple crescent shape that curved gently

Wavy: serpentine or slightest bend at the termination or origin of curved rugae

Circular: rugae with definite continuous ring formation

Based on unification (Rugae joined at origin or termination):

Divergent: two rugae began from same origin but immediately diverge

Convergent: rugae with different origin join on lateral portions

Data obtained were entered into Microsoft excel sheet and transferred to Statistical Package for Social Sciences (SPSS) version 24 for statistical analysis. Mean, median, interquartile range and standard deviation were calculated for quantitative variables. Normality of each variable in the data set was checked using Shapiro-Wilk test. Total number of rugae in both sexes and individual sides showed normal distribution, so independent t-test was used to compare mean number of rugae in between males and females. However, rugae lengths, unification and shapes showed skewed distribution due to which Mann-Whitney U test was used to compare them in between sexes. The level of significance was set at p-value < 0.05.

RESULTS

A total of 1050 rugae were found in the 98 subjects (49 males and 49 females). Out of these, 540 (51.43%) were found in males and 510 (48.57%) were found in females. Among males, 275 (50.18%) and 265 (52.79%) were found in right and left sides respectively. Similarly, 273 (49.82%) were found in right side of females and 237 (47.21%) in left side (Fig. 2). The mean age of males was 24.90 ± 4.19 years and 24.76 ± 3.71 years of females. No correlation of rugae patterns to age was elicited.

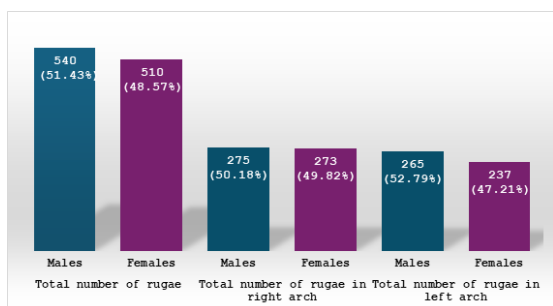


Figure 2. Distribution of total number of rugae present in the study participants.

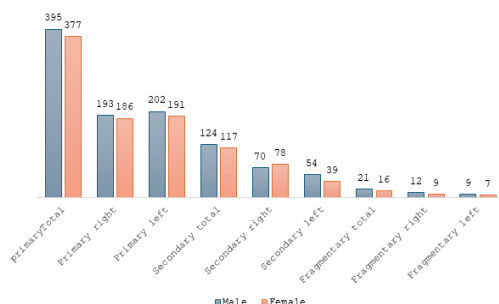


Figure 3. Length of rugae categorization among males and females.

Comparison of mean number of rugae in between males and females is presented in table 1. On comparison, there was no significant difference in mean number of rugae in between males and females (p-value = 0.142). However, males had significantly higher number of rugae in the left side (p-value < 0.030). Comparison in length of rugae between males and females is presented in figure 3 and table 2. No significant difference in number of total primary rugae (p-value = 0.472), primary rugae of right side (p-value = 0.458), primary rugae of left side (p = 0.663), total secondary rugae (p-value = 0.928), secondary rugae of right side (p-value = 0.577), secondary rugae of left side (p-value = 0.081), total fragmentary rugae (p = 0.582), fragmentary rugae of right side (p = 0.583), and fragmentary rugae of left side (p = 0.587), was observed among males and females. On comparison of unification of rugae, significantly higher total diverging pattern was observed in males than in females (p-value = 0.018) but there was no difference in either of right (p-value = 0.082) and left side (p = 0.054). There was similar overall converging (p-value = 0.919), right (p-value = 0.507), and left (p-value < 0.99) patterns among both sexes (Table 3). Comparison of shapes of rugae

Table 1. Comparison of mean number of rugae in between males and females.

Number of rugae	Group	Total number of rugae	Mean±SD	Standard error of mean	p-value*
Total number of rugae in both sides	Males	540	11.02±2.09	0.298	0.142
	Females	510	10.41±2.01	0.287	
Total number of rugae in right side	Males	275	5.61±1.27	0.182	0.888
	Females	273	5.57±1.57	0.224	
Total number of rugae in left side	Males	265	5.41±1.34	0.191	0.030
	Females	237	4.84±1.23	0.176	

*Independent t test

Table 2. Comparison in length of rugae between males and females.

Length of rugae	Group	Median (IQR)	Mean rank	p-value*
Primary total	Males	8 (7-9)	51.53	0.472
	Females	8 (7-9)	47.47	
Primary right	Males	4 (3-5)	51.03	0.578
	Females	4 (3-4)	47.97	
Primary left	Males	4 (3-5)	50.69	0.663
	Females	4 (3-5)	48.31	
Secondary total	Males	2 (1-3.50)	49.76	0.928
	Females	2 (1-3)	49.24	
Secondary right	Males	1 (0-2)	47.95	0.577
	Females	1 (0.50-2.50)	51.05	
Secondary left	Males	1 (0-1.50)	54.18	0.081
	Females	1 (0-1)	44.82	
Fragmentary total	Males	0 (0-1)	50.80	0.582
	Females	0 (0-1)	48.20	
Fragmentary right	Males	0 (0-0)	50.56	0.583
	Females	0 (0-0)	48.44	
Fragmentary left	Males	0 (0-0)	50.50	0.587
	Females	0 (0-0)	48.50	

*Mann Whitney U test

between males and females using Thomas and Kotze's classification is presented in table 4.¹¹ Straight rugae was found significantly higher among females than in males (p = 0.026). However, presence of other patterns had no significant difference in between males and females.

DISCUSSIONS

Human identification investigations typically involve the use of fingerprints, blood group analysis, anthropometry, and dental records.¹³ Fingerprints are the most accurate means of identification, followed by dental records. In forensic odontology, teeth, restorations, bony ridges, and palatal rugae play an important role in identifying individuals.⁶

Table 3. Comparison rugae unification between males and females.

Rugae Unification	Group	Total number	Median (IQR)	Mean rank	p-value*
Converging total	Males	11	0 (0-0)	49.30	0.919
	Females	13	0 (0-0)	49.70	
Converging right	Males	4	0 (0-0)	48.50	0.507
	Females	6	0 (0-0)	50.50	
Converging left	Males	7	0 (0-0)	49.50	<0.99
	Females	7	0 (0-0)	49.50	
Diverging total	Males	65	1 (1-2)	56.00	0.018
	Females	43	0 (0-2)	43.00	
Diverging right	Males	39	1 (0-1)	54.06	0.082
	Females	28	0 (0-1)	44.94	
Diverging left	Males	26	0 (0-1)	54.19	0.054
	Females	15	0 (0-1)	44.81	

*Mann Whitney U test

Table 4. Comparison shapes of rugae between males and females using Thomas and Kotze's classification.¹¹

Shape of rugae	Group	Total number	Median (IQR)	Mean rank	p-value*
Straight total	Males	82	1 (0-3)	43.24	0.026
	Females	115	2 (1-3)	55.76	
Straight right	Males	44	1 (0-1)	42.39	0.009
	Females	66	1 (1-2)	56.61	
Straight left	Males	38	1 (0-1)	46.09	0.204
	Females	49	1 (0-1)	52.91	
Curved total	Males	174	3 (2-5)	49.97	0.869
	Females	130	3 (2-5)	49.03	
Curved right	Males	82	2 (1-2)	49.87	0.895
	Females	49	1 (1-3)	49.13	
Curved left	Males	92	2 (1-3)	51.76	0.416
	Females	81	2 (1-2)	47.24	
Wavy total	Males	127	2(1.5-3.5)	52.10	0.354
	Females	111	2 (1-3)	46.90	
Wavy right	Males	61	1 (0-2)	53.01	0.201
	Females	49	1 (0-2)	45.99	
Wavy left	Males	66	1(0.50-2)	49.60	0.970
	Females	62	1(0.50-2)	49.40	
Circular total	Males	7	0 (0-0)	49.93	0.785
	Females	7	0 (0-0)	49.07	
Circular right	Males	2	0 (0-0)	48.50	0.402
	Females	4	0 (0-0)	50.50	
Circular left	Males	5	0 (0-0)	50.50	0.463
	Females	3	0 (0-0)	48.50	

*Mann Whitney U test

Studies agree that the number of palatal rugae stays stable and is unaffected by growth, aging, tooth loss, or disease.¹⁴ Because the rugae are positioned inside the mouth and protected by the cheeks, lips, tongue, fat pad, teeth, and

bone, they resist trauma and heat, making them useful landmarks in forensic identification.¹⁵ Limited research in Nepal has addressed sexual dimorphism in palatal rugae. This study examined differences in palatal rugae patterns between males and females aged 18-40 years attending Dhulikhel Hospital, KUSMS, and explored their use in gender identification.

Number of Rugae: In the present study, the number of palatal rugae was slightly higher in males (540) compared to females (510). A greater number of rugae in males has also been reported by Thabitha et al., Gadicherla et al., Kamala et al., Indira et al., Mittal et al., Shetty et al., Pappu et al., and Oberoi et al.^{6,16-22} However, the findings of the current study are not consistent with those of Gaikwad et al, Shrestha et al., Gondivkar et al., Kotrashetti et al. and Mounika et al.^{13,23-26} However, males exhibited a significantly higher number of rugae on the left side. These observations are in agreement with the findings of Dohke et al. and Surekha et al.^{27,28} In contrast, Thabitha et al. and Indira et al. reported that the left side of the palate contained fewer rugae than the right side.^{6,18}

Length of rugae: Males had a higher number of primary, secondary, and fragmentary rugae, but no significant differences were observed between sides or genders. These results align with findings of Kapali et al. in Australian Aborigines, Bajracharya et al. in the Nepalese population, Shetty et al. in the Mangalorean Indian population.^{12,14,20} According to Dohke et al., this may be attributed to the phenomenon of regressive evolution, which predominantly affects the right side of the palate and is more evident in females.²⁷ In contrast in Thabitha et al. study of Nalgonda children, females had a significantly higher number of primary rugae than males.⁶ Shetty et al. similarly reported that Mysorean males and Tibetan females exhibited a greater number of primary rugae than their respective counterparts.²⁹

Shape of rugae: In terms of rugae shape, straight rugae were significantly more common in females than in males. The present study found that the curved pattern was the most predominant in both genders, followed by wavy, straight, and circular patterns. These results align with Gadicherla et al., who observed curved patterns predominating in females and Shetty et al., who reported a predominance of curved rugae in Indian males.^{16,29} In contrast, wavy rugae were more common in studies by Thabitha et al. (Nalgonda children), Kapali et al.(Australian Aborigines and Caucasian populations), Bajracharya et al., Shrestha et al., (Nepalese population), Kotrashetti et al., Surekha et al., Dahal et al., Nayak et al.^{6,12,14,23,25,28,30,31} The circular pattern was the least observed in our study, contrasting with Kapali et al., who reported straight rugae as the least common.¹² Additionally, straight rugae were significantly more frequent in females than in males, consistent with the findings of Balgi et al., Harchandani et al. reported that Western Indian females predominantly exhibited straight rugae, whereas curved

rugae were more common in Northern Indian females.^{32,33}

Rugae unification: Another finding of our study was that diverging rugae were significantly more common in males, consistent with the observations of Thabitha et al. and Mounika et al.^{6,26} In contrast, Fahmi et al. reported that Saudi females exhibited more converging rugae than males, and Azab et al. found the converging form to be more prevalent than diverging.^{34,35} Meanwhile, Shetty et al., Surekha et al. and Shetty et al. noted that rugae unification did not follow any specific trend.^{20,28,29}

Digital techniques have also been employed to compare ante-mortem and post-mortem rugae records. Using advanced palatal rugae comparison software, Hemanth et al. reported an identification accuracy of 99%.³⁶

The present study supports earlier findings, confirming the potential of palatal rugae patterns in gender determination and their reliability as a tool for identification due to their uniqueness and stability. Their application in gender determination is further favored by low cost, simplicity, and reliability. Variations in rugae pattern, number, and shape exist not only between individuals but, to a lesser extent, between the right and left sides of the same person.

This study included a limited sample size of 98 subjects; future studies with larger samples would be beneficial. The age range of participants could be expanded in subsequent research. Multicenter studies are needed to include

diverse populations and ethnic groups. The method relies on the availability of ante-mortem records of palatal rugae for identification purposes. While many rugae features in our study were similar to other populations, but none matched exactly, likely due to genetic variation. Several studies have emphasized the influence of both genetic and environmental factors on rugae patterns.

CONCLUSION

In the present study, males exhibited a higher number of palatal rugae on the left side, and diverging unification was the most predominant pattern in male Nepalese subjects. Straight rugae were significantly more common in females. Although primary rugae were more, no significant difference was observed in rugae length. Within the study's limits, palatal rugae show potential for gender identification and may serve as a supplementary tool alongside other reliable forensic methods. While the study highlights the forensic significance of palatal rugae, its findings are limited by the sample size and underscore the need for further research in the Nepalese population.

ACKNOWLEDGEMENTS

We sincerely acknowledge Dr. Swagat Kumar Mahanta and Dr. Sirjana Dahal for their valuable support and guidance in the biostatistical analysis of this study.

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