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Variations in palatal rugae amongst individuals in Western Maharashtra and their role in forensic identification

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Abstract

Background: This observational study investigates variations in palatal rugae patterns among individuals from Western Maharashtra to assess their potential as a forensic tool for sex determination and identification. Palatal rugae offer unique, stable patterns resistant to environmental factors, making them valuable in forensic odontology when conventional methods fail. Palatal rugae, ridges on the anterior hard palate, exhibit individuality and durability, aiding applications in forensics, anthropology, and dentistry. Prior research shows inconsistent sex dimorphism in rugae traits across populations, highlighting the need for region-specific data from Western Maharashtra.

Objectives: The study compares rugae number, shapes, unification patterns, and palatal vault characteristics between males and females aged 18-30 years. It evaluates these features' utility for biological sex differentiation in forensic contexts.

Methods: Dental casts from 60 participants (30 males, 30 females) were analyzed using Thomas and Kotze classification for shapes (straight, curved, wavy, circular) and unification (converging, diverging). Rugae counts, lengths, and vault types were measured; statistical tests included Student's t-test and chi-square ($p<0.05$ significant).

Results: Males had significantly higher mean total rugae (9.30 ± 0.65) than females (8.30 ± 1.12; $p=0.001$). No significant sex differences appeared in shapes (wavy predominant at 63.3%), unification, or vault types (medium most common at 53.3%; $p>0.05$).

Conclusion: Rugae count demonstrates sexual dimorphism in this population, supporting its role as a supplementary forensic identifier, while other patterns show uniformity across sexes. These findings align with select global studies and underscore population-specific genetic influences on rugae morphology.

Keywords: Forensic odontology, Western Maharashtra, palatal rugae, sex determination

Introduction

Forensic odontology is the branch of dentistry that applies dental knowledge and techniques to the administration of justice, primarily for the identification of individuals in criminal investigations and mass disasters by leveraging dental structures for human identification when conventional methods like fingerprints or DNA prove unfeasible. It includes procedures such as comparison of dental records, age and sex estimation, bite mark analysis, and DNA extraction from teeth. One important method used in forensic odontology is the study of palatal rugae, known as rugoscopy [1]. Palatal rugae are irregular ridges located on the anterior part of the hard palate behind the incisive papilla. These ridges are unique to each individual, remain relatively stable throughout life, and are protected within the oral cavity, making them resistant to decomposition, trauma, and high temperatures [2]. Because of these characteristics, palatal rugae can be used for personal identification, especially when fingerprints and other identifying features are unavailable. By comparing antemortem dental casts or digital records with postmortem findings, forensic experts can help establish the identity of unknown individuals [1, 3].

Nestled securely within the oral cavity, their anatomical positioning provides robust protection against external trauma, scorching temperatures, and environmental wear, ensuring patterns remain intact even in challenging scenarios like mass disasters or decomposed remains. Beyond these core strengths, their application in forensic odontology stands out due to additional practical merits—minimal financial investment, straightforward procedural simplicity, and consistently high reliability—making them a versatile, efficient tool for victim identification when traditional methods like fingerprints or DNA prove inaccessible.

The need for this study arises from the limited number of existing studies on its application in human identification. Therefore, the core aim of this study was to evaluate the viability and efficacy of palatal rugae patterns as a dependable tool for determining biological sex [4].

Therefore, this study aims to compare palatal rugae patterns between males and females by examining their number and shapes, in order to identify significant differences and assess their usefulness in forensic odontology.

Case Examples

During the 2004 Indian Ocean tsunami and various plane crashes, maxillary impressions relying on rugae patterns identified victims without viable facial structures. Rugae's resilience has also resolved identification in burn victims where teeth were obliterated [5, 6].

Materials and Methodology

This Observational study was carried out in the population of Western Maharashtra. A pilot study was carried out amongst 10 participants based on the result of the pilot study the sample size of 60 was calculated. The study sample included 60 participants with equal number of males and females between 18 – 30 years of age; all the participants had full set of permanent dentitions.

Inclusion criteria

1. Complete set of Permanent Dentitions, except the third molars.
2. Patients without any Prosthesis.
3. Patients without any Orthodontic treatment or Braces.
4. Patients devoid of Congenital Abnormalities, Inflammation or Trauma.

Exclusion criteria

1. Individuals with any Lip or Palate Anomaly such as cleft lip or cleft palate.
2. Individuals with any Prosthesis.
3. Individuals undergoing Orthodontic Treatment.
4. Individuals with bony and soft tissue protuberances, active lesions, and trauma of palate.

All the patients who participated in the study were explained about the study in their known language and consent was taken. Patients were made comfortably seated on a dental chair and the detailed history along with the demographic data was recorded. Further, alginate impression of the maxillary arch was taken using perforated impression trays to obtain accurate reproduction of the palatal rugae patterns. Alginate impressions were rinsed under running tap water, and casts were poured using high-strength plaster. The resulting models were inspected to ensure they were free of voids or defects, particularly in the anterior two-thirds of the hard palate. The casts were then sterilized, with their bases trimmed parallel to the occlusal plane and allowed to dry completely. Finally, the rugae patterns were sharply outlined using a graphite pencil under proper lighting and examined macroscopically. [7]

Identification Method

Rugae patterns were classified according to the Thomas and Kotze classification of rugae pattern (1983) (shown in figure 1) [1], which categorizes them by length, shape, and unification characteristics. Primary rugae measure over 5 mm in length, secondary rugae range from 3–5 mm, and fragmentary rugae are shorter, at 2–3 mm.

Shapes include straight (running directly from origin to end), curved (gentle crescent-like arcs), wavy (serpentine or undulating), and circular (complete, unbroken rings). Unification occurs when rugae join at their origins or terminations; diverging rugae share a common starting point before branching apart, while converging rugae originate separately but meet at a shared endpoint [8].

A midline was drawn along the midpalatine raphe, starting from the incisive papilla and extending to the posterior limit of the rugae on the palate. This line bisected the rugae into left and right halves. The total number of palatal rugae on each side of the raphe was then counted and noted. The length of each rugae was measured end-to-end using a pointed divider and scale [9].

The length of the curvy and wavy rugae was measured using a flexible thread, which was carefully adapted along the entire contour to follow its natural curvature. The thread was kept taut without stretching, and the start and end points were clearly identified. The measured length was then transferred onto a ruler with the help of a divider to obtain the value in millimeters. Each measurement was repeated to ensure accuracy, and the average was recorded [9]. (as shown in figure 2)

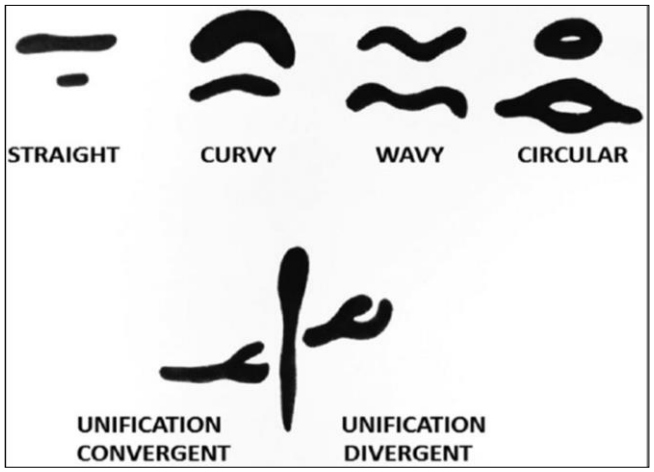

Fig 1: Thomas and Kotze classification palatal rugae pattern [1]

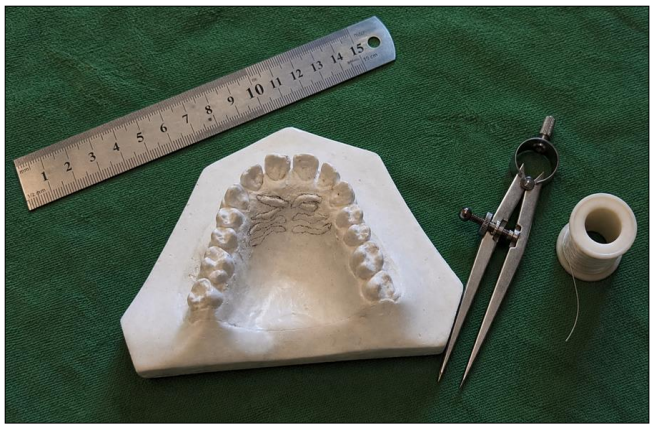

Fig 2: Image showing highlighted palatal rugae patterns and armamentarium used in measuring the palatal rugae

Results

The study included 60 participants, comprising 30 males (50%) and 30 females (50%). The mean age of the participants was 23.0 ± 2.0 years, with males having a mean age of 23.2 ± 2.1 years and females 22.8 ± 1.9 years. The mean total number of palatal rugae was higher in males (9.30 ± 0.65) compared to females (8.30 ± 1.12), indicating a greater average number of rugae patterns among males (shown in table no I).

The predominant palatal rugae shape observed in both male and female groups was the wavy pattern, making it the most common shape overall in the study population. The mean palatal vault height in males was recorded as 12.4 ± 1.8 mm, while females showed a slightly lower mean value of 11.9 ± 1.6 mm. The overall mean palatal vault height for the total sample was 12.15 ± 1.7 mm (shown in table no III) Based on the classification of palatal vault types, the medium vault type was found to be the most prevalent among the participants. In males, 14 individuals (46.7%) exhibited a medium vault, whereas 18 females (60%) showed the same type, contributing to a total of 32 participants (53.3%). Deep palatal vaults were observed in 12 males (40%) and 8 females (26.7%), accounting for 20 participants (33.3%) overall. The shallow vault type was the least common, with equal distribution among males and females, where 4

participants (13.3%) from each group demonstrated shallow palatal vaults, totaling 8 participants (13.3%) (shown in table no IV).

Unification occurs when two rugae are joined at their origin or termination. The comparison of left-side unification patterns between males and females showed that the diverging pattern was more common in both groups, being observed in 16 males and 20 females, while the converging pattern was seen in 14 males and 10 females (shown in table V). The comparison of right-side unification patterns showed equal distribution among males and females. Converging unification was observed in 17 males and 17 females, while diverging unification was seen in 13 males and 13 females (shown in table VI).

Among the parameters evaluated, the total number of palatal rugae emerged as the primary distinguishing characteristic between males and females. Male participants demonstrated a significantly greater mean rugae count than females, indicating that rugae number may serve as a useful indicator in sex differentiation. In contrast, other morphological features—including rugae shape, unification pattern, and palatal vault type—showed comparable distributions in both sexes, with wavy rugae, diverging unification, and medium palatal vault being the predominant patterns irrespective of gender.

Table 1: Demographic Characteristics of Study Population

Variable	Male (n = 30)	Female (n = 30)	Total (n = 60)
Number (%)	30 (50%)	30 (50%)	60 (100%)
Mean Age (years)	23.2 ± 2.1	22.8 ± 1.9	23.0 ± 2.0
Mean Total Rugae	9.30 ± 0.65	8.30 ± 1.12	-

Values are expressed as mean ± standard deviation

Table 2: Comparison of Total Number of Palatal Rugae Between Male and Female

Gender	Mean	Standard deviation
Male	9.30	0.65
Female	8.30	1.12

t = Student's t-test; $p < 0.05$ considered statistically significant.

Male participants exhibited a higher mean number of palatal rugae (9.30 ± 0.65) compared to females (8.30 ± 1.12), indicating a statistically significant difference ($p < 0.001$) (shown in table II and figure 3)

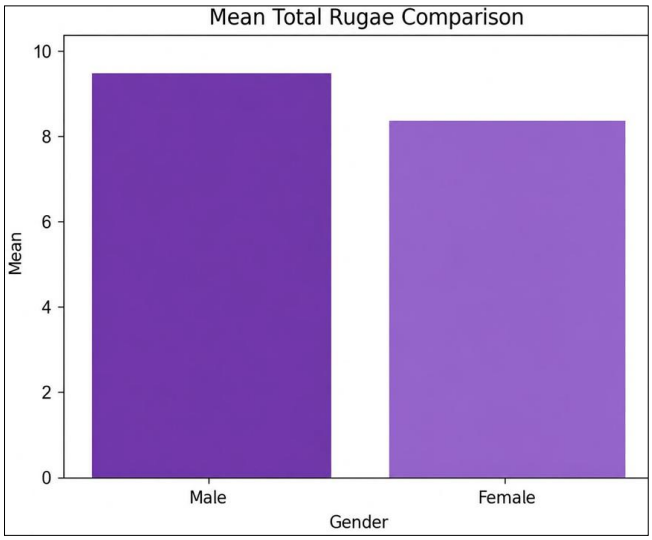

Fig 3: Comparison of Mean Total Number of Palatal Rugae

Table 3: Morphological Characteristics of Palatal Rugae

Variable	Male (n = 30)	Female (n = 30)	Total (n = 60)
Predominant Shape	Wavy	Wavy	Wavy
Palatal Vault Mean (mm)	12.4 ± 1.8	11.9 ± 1.6	12.15 ± 1.7
Vault Type – Deep (n, %)	12 (40%)	8 (26.7%)	20 (33.3%)
Vault Type – Medium (n, %)	14 (46.7%)	18 (60%)	32 (53.3%)
Vault Type – Shallow (n, %)	4 (13.3%)	4 (13.3%)	8 (13.3%)
Predominant Unification	Diverging	Diverging	Diverging

Values are mean ± standard deviation; percentages in parentheses.

The medium palatal vault type was most prevalent (53.3%), followed by deep (33.3%) and shallow (13.3%) types, indicating a predominance of moderate vault morphology. (as shown in figure 3)

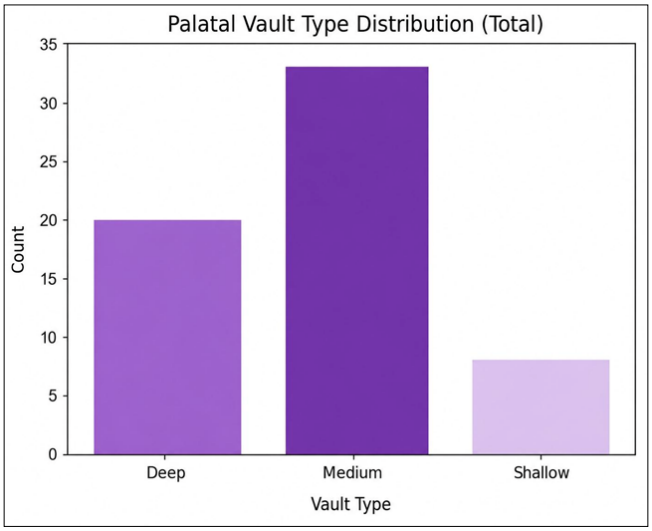

Fig 3: Distribution of Palatal Vault Types

Table 4: Comparison of Rugae Shape Pattern Between Male and Female

Shape Pattern	Male (n = 30)	Female (n = 30)	Total (n = 60)	p-value
Wavy	18 (60%)	20 (66.7%)	38 (63.3%)	
Curved	7 (23.3%)	6 (20%)	13 (21.7%)	
Straight	5 (16.7%)	4 (13.3%)	9 (15%)	
Circular	0 (0%)	0 (0%)	0 (0%)	
χ^2 value				0.52
p-value				>0.05

Values are expressed as number (percentage); χ^2 = chi-square test; $p > 0.05$ indicates no statistically significant difference.

The analysis of the total study population (n = 60) showed that the wavy pattern was the most predominant palatal rugae shape, observed in 38 participants (63.3%). The curved pattern was found in 13 participants (21.7%), while the straight pattern was observed in 9 participants (15%). (as shown in figure 4)

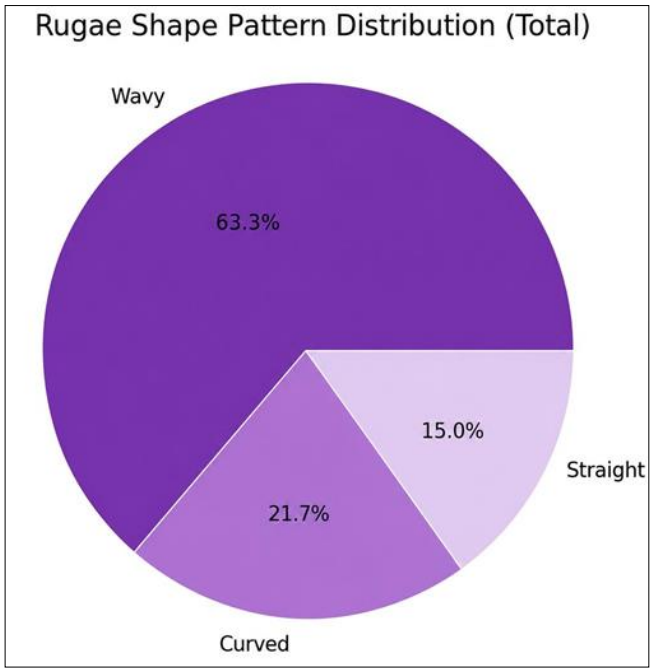

Fig 4: Distribution of Palatal Rugae Shape Patterns

Table 5: Left Side Unification Pattern among Male and Female

Unification (Left)	Male	Female
Converging	14	10
Diverging	16	20
χ^2 value	1.07	
p-value	>0.05	

χ^2 = chi-square test; $p > 0.05$ not statistically significant.

Table 6: Right Side Unification Pattern among Male and Female

Unification (Right)	Male	Female
Converging	17	17
Diverging	13	13
χ^2 value	0.00	
p-value	1.00	

χ^2 = chi-square test; $p = 1.00$ indicates no difference.

Discussion

Bajracharya and colleagues observed that primary palatal rugae outnumbered secondary and fragmentary ones in Nepalese participants. They also noted the wavy pattern as the most common, followed by curved, straight, and circular types. Importantly, no significant sex-based differences emerged in rugae count or patterns [10]. These results align closely with our current findings. Similarly, Santos and Calder's work on Portuguese individuals revealed no notable sexual dimorphism in rugae shapes [11].

Smirti *et al*. analyzed 252 dental casts and found wavy patterns to be the most frequent across both sexes, trailed by curved, straight, and circular ones—mirroring our study. Sex differences were absent except for the circular pattern [12].

In Egyptian subjects, Azab *et al*. identified wavy rugae as predominant, followed by straight and circular forms. Converging rugae appeared more often than diverging ones, with no overall sex differences aside from curved shapes, which were notably higher in females [13].

Ahmed and Hamid's research showed males with more rugae overall. Primary rugae dominated over secondary and fragmentary in both sexes, with wavy patterns leading, then curved and straight. This matches our observations, though they detected sexual dimorphism in primary, converging, and nonspecific patterns. Their regression analysis, however, found no significant differences in continuous variables [14].

Shrestha *et al*. reported wavy shapes as the top pattern in Nepalese people, followed by straight and circular, with primary rugae most common in both sexes—consistent with ours. Yet, they noted significant differences in females for secondary, fragmentary, straight, and perpendicular rugae, which contrasts with our results [15].

By contrast, Gautam *et al*. found males had significantly more rugae than females. Straight patterns prevailed in both groups, but no significant link existed between patterns and sex [16].

Sheikhi *et al*.'s study on Iranians linked rugae patterns to sex and ethnicity, with straight shapes most common, then wavy and curved. For males, straight (26%) led, followed by wavy (21%) and branching with divergence (16%); females mirrored this with straight (26%), wavy (21%), and curved (17%). These patterns differ from ours, and discriminant analysis failed to reliably sex the casts [17].

Another study showed no sex differences in average rugae numbers, but males had longer rugae on average. Straight patterns were more frequent in females, with significant variations in length and shape supporting rugae as a sex identification tool [18].

Research on Nalgonda children highlighted wavy patterns as dominant in both sexes, followed by curved, straight, and circular. Primary rugae were most prevalent, though females had more primary rugae and males more secondary ones. Diverging types exceeded converging in males on both palate sides [19].

Godicherla *et al*. noted wavy patterns in 62% of males and curved in 54% of females, with significant sex differences for curved, wavy, and straight types. Females showed more convergence in rugae unification, while males had more divergence [4].

Madhankumar *et al*. identified straight and curved shapes as most common across sexes, advocating rugae counts and unification patterns as aids for human identification due to key differences [20].

While various studies report significant sex differences in rugae number, size, or shape, results vary widely. Nepalese patterns, in particular, diverge from other groups, likely influenced by genetics in embryogenesis and postnatal development.

The study has several limitations that should be acknowledged. It was conducted with a relatively small sample size and participants drawn from a limited population group, which may restrict the generalizability of the findings to wider ethnic or regional populations. The investigation considered only age and gender differences, omitting other factors that might influence palatal rugae patterns, and variations in recording and interpretation may have introduced observer bias. Additionally, as a cross-sectional study, it could not assess long-term changes in rugae patterns. To address these issues, future research should include larger, more diverse samples across different ethnic groups, employ advanced digital imaging and standardized methods for more precise analysis, explore associations between palatal rugae and other forensic parameters to improve human identification, and undertake longitudinal studies to evaluate changes in rugae patterns over time.

Conclusion

In conclusion, this study shows the key forensic value of palatal rugae patterns for identifying people and determining sex in the Western Maharashtra population. Men had a much higher average number of rugae than women ($p<0.05$), making rugae count a helpful tool for telling sexes apart. But rugae shape (wavy most common at 63.3%, then curved at 21.7% and straight at 15%), joining patterns (diverging on the left, even on the right), and roof-of-mouth type (medium at 53.3%) showed no clear sex differences ($p>0.05$). This points to steady traits in this group.

These reliable features, plus rugae's safe spot inside the mouth that resists rot, heat, and injury, make them a cheap, easy-to-use aid for forensics when DNA or fingerprints can't be used—like in disasters or badly decayed bodies. These local findings fix past mixed results on sex differences. Future studies across groups with digital photos could improve accuracy in dental forensics.

References

1. Sabarigirnathan C, Vinayagavel K, Meenakshi A, Selvamani C, Sriramprabu G, Sivasakthikumar S, *et al*. Palatal rugae in forensic odontology: a review. IOSR J Dent Med Sci,2015:14(10):83–87.
2. Shetty DK, Mali S, Divakar HD, Amit P, Dhairaysheel E, Harsh U. Palatal Rugae Patterns as a Bioindicator for Forensic Identification in Kodava and Tibetan Populations of India. J Int Oral Health,2015:7(Suppl 2):57-9.
3. Shetty DK, Mali S, Hegde D, Patil A, Edake D, Unadkat H, *et al*. Palatal rugae patterns as a bioindicator for forensic identification in Kodava and Tibetan populations of India. J Forensic Dent Sci, 2015, 7(3).
4. Gadicherla P, Saini D, Bhaskar M. Palatal rugae pattern: An aid for sex identification. J Forensic Dent Sci,2017:9(1):48.
5. Wazir SS, Arora P, Srivastava R, Rastogi S. Forensic application of palatal rugae in dental identification. J Nepal Med Assoc,2015:53(199):151–155.
6. Hemanth M, Vidya M, Shetty N, Karkera BV. Identification of individuals using palatal rugae: Computerized method. J Forensic Dent Sci,2010:2(2):86-90.
7. Jaisingh R Palatal Rugae Patterns as an Adjuvant to Gender Determination in Forensic Identification Procedures in a Paediatric Population. J Forensic Sci Criminol,2016:3:305.
8. 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,2015:27:9
9. Mounika G, Sahi KB, Deepika AD, Naidu H, Malyadri A. Palatal Rugae pattern in Gender Identification - A Forensic Study. 2022:7(1):47-57
10. Bajracharya D, Vaidya A, Thapa S *et al*. Palatal Rugae Pattern in Nepalese Subjects. Orthod J Nepal,2013:3(2):36–9.
11. Santos C, Caldas IM. Palatal rugae pattern in a Portuguese population: a preliminary analysis. J Forensic Sci,2012:57(3):786–8
12. Smriti K, Gupta R, Pentapati KC *et al*. Sex assessment by morphological analysis of palatal rugae patterns in a South Indian adult population. Clin Cosmet Investig Dent,2021:13:77–81.
13. Azab SMS, Magdy R, Sharaf El *et al*. Patterns of palatal rugae in the adult Egyptian population. Egypt J Forensic Sci,2016:6(2):78–83.
14. Ahmed AA, Hamid A. Morphological study of rugae palatine in Sudanese Nubians. Folia Morphol,2015:74(3):303–10.
15. Shrestha A, Shrestha S, Marla V *et al*. Patterns of palatal rugae as an indicator of identification in young adults of Nepal. J Coll Med Sci,2017:13(2):241–5.
16. Gautam N, Patil SG, Gopi Krishna R *et al*. Association of palatalrugae pattern in gender identification: An exploratory study. J Contemp Dent Pract,2017:18(6):470–3.
17. Sheikhi M, Zandi M, Ghazizadeh M. Assessment of palatal rugae pattern for sex and ethnicity identification in an Iranian population. Dent Res J (Isfahan),2018:15(1):50–6.
18. Kathuriya P, Balgi P, Bhalekar B *et al*. Study of palatal rugae pattern in gender identification. J Dent Allied Sci,2014:3(1):13.
19. Thabitha RS, Reddy RE, Manjula M *et al*. Evaluation of palatal rugae pattern in establishing identification and sex determination in Nalgonda children. J Forensic Dent Sci,2015:7(3):232.
20. Madhankumar S, Natarajan S, Maheswari U *et al*. PalatalRugae Pattern for Gender Identification among Selected Student Population in Chennai, India. J Sci Res Reports,2013:2(2):491–6.