Original Article

# The Application of Palatal Rugae for Sex Discrimination in Forensic Medicine in a Selected Iranian Population

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Received: 9 October 2017
Revised: 10 December 2017
Accepted: 28 January 2018

## Abstract

**Background:** Palatal rugae have been shown to be associated with racial and geographical variations and are known to be useful in sex identification. The present study aimed to assess palatal rugae patterns in a sample Iranian population and to compare the results with those from other studied populations.

**Methods:** During summer 2017, 130 pre-orthodontic plaster casts from patients aged 17-25 years (65 males and 65 females) were obtained from the Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran. The castes were evaluated using the classification given by Thomas and Kotze followed by recording the rugae lengths and shapes. The data were analyzed with the SPSS statistical software package (version 15.0) using the unpaired *t* test and Chi-square test. $P<0.05$ were considered statistically significant. Additionally, discriminant function analysis was applied to determine the applicability of palatal rugae patterns as a tool to aid sex identification.

**Results:** The rugae count showed an insignificant difference between the Iranian males and females. The primary rugae were most common in both sexes followed by the secondary and fragmentary. Significant differences were observed between the sexes and the number of primary rugae in males ($P=0.03$) and fragmentary rugae in females ($P=0.04$) on the left side of the palate. A significant difference in the straight and diverging unification types was observed, which was highest in males ($P=0.01$) and females ($P=0.03$), respectively. Discriminant function analysis enabled sex identification with an accuracy of 70%.

**Conclusion:** Palatal rugae is shown to be an appropriate tool for sex identification in an Iranian population. Further studies with a larger sample size are required for a comprehensive outcome.

Please cite this article as: Malekzadeh AR, Pakshir HR, Ajami Sh, Pakshir F. The Application of Palatal Rugae for Sex Discrimination in Forensic Medicine in a Selected Iranian Population. Iran J Med Sci. 2018;43(6):612-622.

**Keywords** ● Forensic medicine ● Palatal rugae ● Sex identification ● Iranian population

## What's Known

- Palatal rugae characteristics are permanent and unique to each person.
- Worldwide, different palatal rugae patterns have been shown to be associated with specific racial groups and are known to be useful in sex identification.

## What's New

- The first published data on palatal rugae morphology of the Iranian population.
- The application of palatal rugae for sex identification is applied to a sample Iranian population and the results are compared to those from other countries.

## Introduction

Forensic medicine plays a pivotal role in criminal and civil law. In this context, the science of dentistry is also used in human identification; known as forensic dentistry or forensic odontology.[1] Human characteristics such as fingerprints, DNA, and dental records are the most frequent identification techniques in forensic

medicine.[2,3] However, visual identification and the use of fingerprints are hindered by postmortem changes associated with time, temperature, and humidity. Compared to teeth, other body parts disintegrate quicker. However, regarding sex identification, teeth alone cannot be solely relied upon because of possible alterations due to dental treatment between the last dental record and the death of the individual. Although DNA profiling is accurate, it is expensive and time-consuming for use in large populations.[4] In circumstances where it is difficult to identify a dead person by fingerprints or dental records, palatal rugae could be an alternative as they possess unique characteristics. Therefore, for human identification, palatal rugae (as well as lip grooves) can be utilized successfully.[3] Considering its stability and accuracy, which is equivalent to that of fingerprints, palatal rugae patterns are unique to an individual.[5-7] Palatal rugae also remain permanent and thus clinicians and scientists can use their characteristics to establish an identity through discrimination.[8]

Past studies have shown the importance of palatal rugae for human identification in situations such as accidents or a mass disaster. It is suggested that the examination of palatal rugae, also called palatal rugoscopy or palatoscopy, can be utilized as an identification technique if antemortem dental records exist.[2, 3] Palatoscopy and cheiloscopy are equivalent to dental, fingerprint, and DNA identification techniques.

Palatal rugae are the asymmetrical and irregular elevations of the mucosa. They appear towards the third month of intrauterine life (12$^{th}$ to 14$^{th}$ weeks of prenatal life) and are positioned in the anterior third of the palate behind the incisive papilla.[3, 9, 10] Because their individual morphological characteristics are stable throughout life, rugoscopy can play an important role in medico-legal identification.[7] The form of the palatal rugae does not alter due to disease, chemical attack, or trauma. Considering their anatomical position inside the mouth, they are well preserved even after third-degree burns. Hence, they are well protected and more resistant to decomposition and thermal effect.[11-13] Palatal rugae are stable landmarks and once formed, they do not undergo any changes except in length (due to normal growth) and remain in position throughout a person's life.[14]

Rugae are measured in a straight line between the origin and termination. As shown in table 1, they are grouped into three categories, namely primary (5 millimeters or more), secondary (3 to 5 millimeters), and fragmentary (2 to 3 millimeters). Note that rugae <2 millimeters are discarded. The anatomic position of these transverse ridges aid in oral sucking and swallowing, taste perception, and participate in speech, particularly the "s" and "sh" phonemes.[15] In clinical dentistry, palatal rugae due to their stable nature can be used as a landmark during orthodontic treatment,[8] cleft palate surgeries,[16] palatal prosthesis,[17] and medicolegal identification.[18] In both sexes, transverse palatal rugae width and length increases with age, and their growth ends once the somatic growth stops.[19] Moreover, there is a significant association between rugae patterns and ethnicity. It is reported that palatal rugae patterns are unique to a specific community.[20]

Due to the lack of any published data on palatal rugae morphology of the Iranian population, the present study aimed to assess the palatal rugae patterns and report the significant rugae patterns in a sample Iranian population. The main goals and objectives were: (i) to study the individuality of palatal rugae patterns such as length, shape, and unification in males and females, (ii) to compare the rugae patterns among males and females and its usefulness in sex identification, and (iii) to compare the results with those from other studied populations.

**Table 1:** Descriptive analysis of the total number of palatal rugae together with mean values

| Palatal rugae | N | Total number of rugae | Mean±SD |
|---|---|---|---|
| Prevalence | 130 | 1,302 | 10.01±2.28 |
| Primary | 130 | 1,142 | 8.73±1.65 |
| Secondary | 130 | 149 | 1.15±1.37 |
| Fragmented | 130 | 11 | 0.08±0.33 |
| Straight | 130 | 357 | 2.75±1.75 |
| Wavy | 130 | 457 | 3.51±1.71 |
| Curve | 130 | 377 | 2.90±1.94 |
| Diverging | 130 | 58 | 0.45±0.68 |
| Converging | 130 | 26 | 0.20±0.53 |
| Circular | 130 | 8 | 0.06±0.27 |
| Cross-link | 130 | 19 | 0.15±0.40 |

## Materials and Methods

During summer 2017, 130 pre-orthodontic dental casts from the Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences (Shiraz, Iran) were evaluated. The sample size was calculated to detect a difference of magnitude 1 in the mean number of rugae between the two sexes with expected population SD=2, alpha=0.05, and power=80%. The calculated sample size was equal to 65 for each sex group. Hence, the selected casts belonged to 65 males and 65 females aged 17-25 years. The dental casts were coded by the administrative staff to obscure personal information of the patients. Based on the archived health records, all individuals were healthy and free of congenital abnormalities, inflammation, trauma, or orthodontic treatment. All casts were free of air bubbles or voids, especially at the anterior third of the palate. The classification system of Thomas et al.[21] was used for rugae identification. It included the study of the total number, length, shape, and unification pattern of rugae. Rugae shapes and patterns were outlined by two independent examiners using a sharp graphite pencil. The examiners were trained and calibrated to ensure uniform elucidations and concordant registration. Kappa statistics was used to access inter-examiner reliability to determine rugae patterns accurately.

*Length Measurement*

To record the rugae length, the starting point of rugae at mid-palatine raphe to the endpoint of rugae was measured transversely. In case of a circular shape, the maximum diameter was taken into account. All measurements were performed under magnification using a slide caliper to an accuracy of 0.01 mm.

*Evaluation of Shape*

As shown in figure 1, the shape of individual rugae was classified as follows:

1. Straight: Directly from origin (mid-palatine raphe) to termination.
2. Curve: Gently curved with a crescent shape. Circular with a continuous ring formation.
3. Circular: Appears as a ring formation.
4. Wavy: In the form of a twist.
5. Unification: When rugae have two arms joined either at their origin or at termination, which might be diverging (when the two arms of the rugae begin from the same origin and bifurcate transversely) or converging (when the two arms of rugae arise with different origins and converge transversely) types.[22]

*Statistical Analysis*

The readings for each cast were recorded and observations were transcribed in a tabular format using Microsoft Excel 2007. The data were then exported to the SPSS statistical software package,

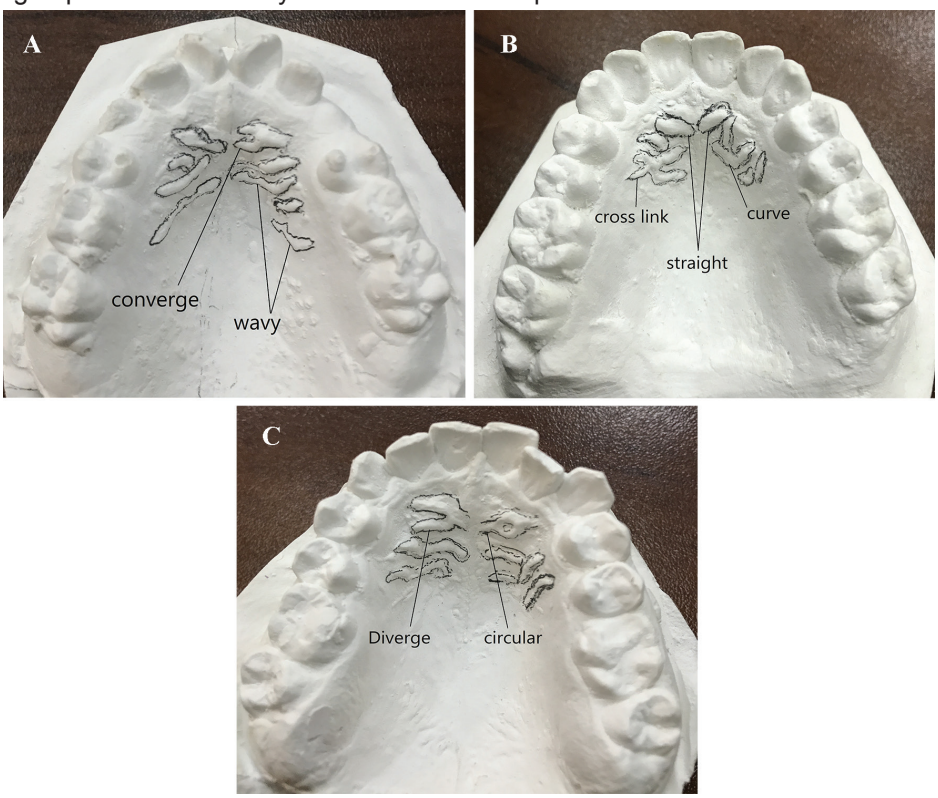


**Figure 1:** Maxillary upper stone casts showing different individual rugae patterns. (A) converging unification and wavy, (B) cross-link, curve, and straight, (C) diverging unification and circular

version 15.0, (SPSS Inc., Chicago, Illinois, USA) for further analysis. Unpaired *t* test and Chi-square test were used for the comparison of the mean and relationship between the attributes. In all tests, the confidence interval and P value were set at 95% and <0.05, respectively. In addition, the obtained data were subjected to discriminant function analysis to determine the applicability of palatal rugae patterns as a tool to aid sex identification.

## Results

Based on Kappa statistics, the inter-examiner reliability for the assessment of palatal rugae was as high as 89%. The mean prevalence of the total number of palatal rugae was 10.01. The highest mean value was associated with the primary type (mean=8.37) compared with the secondary and fragmentary (mean: 0.08 and 1.15, respectively). In terms of rugae shapes, as shown in table 1, the mean of the total number of rugae in descending order was wavy (3.51±1.71), curve (2.90±1.94), straight (2.75±1.75), diverging unification (0.45±0.68), converging unification (0.20±0.53), cross-link (0.15±0.40), and circular (0.06±0.27).

Statistical analysis using independent *t* test showed insignificant differences in the total number of palatal rugae between the Iranian males and females. In addition, the prevalence of palatal rugae in both the right and left sides of the palate was more common in males (mean: 5.14 and 5.11, respectively) compared to females (mean: 4.94 and 4.85, respectively) without any statistical significance (table 2).

The number of primary rugae in males (n=583) was not significantly more common than in females (n=559). The total number of primary rugae was most common (n=1,142) in both sexes followed by secondary (n=149) and fragmentary (n=11). The number of primary and secondary rugae were more common in males, while the fragmentary rugae were more common in females (n=8) than in males (n=3) (table 3).

The distribution of the rugae length on the left side of the palate showed that the number of secondary rugae in both males and females was comparable (P=0.914). There were significant differences between the sexes and the number of primary (P=0.03) and fragmentary (P=0.04) rugae on the left side of the palate. The primary rugae were more common in males, while the fragmentary rugae were more common in females (n=4) compared to males (n=0) (table 4).

**Table 2:** The prevalence of palatal rugae in males and females

| Prevalence | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Right side | Male | 65 | 334 | 5.14±1.38 | 0.487 |
| | Female | 65 | 321 | 4.94±1.36 | |
| Left side | Male | 65 | 332 | 5.11±1.30 | 0.175 |
| | Female | 65 | 315 | 4.85±1.23 | |
| Total | Male | 65 | 666 | 10.25±2.30 | 0.268 |
| | Female | 65 | 636 | 9.78±2.25 | |

**Table 3:** Distribution of palatal rugae length in males and females

| Palatal rugae | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Primary | Male | 65 | 583 | 8.97±1.74 | 0.118 |
| | Female | 65 | 559 | 8.49±1.53 | |
| Secondary | Male | 65 | 77 | 1.19±1.33 | 0.662 |
| | Female | 65 | 72 | 1.11±1.41 | |
| Fragmented | Male | 65 | 3 | 0.04±0.21 | 0.287 |
| | Female | 65 | 8 | 0.12±0.41 | |

**Table 4:** Distribution of palatal rugae length on the left side of the palate in males and females

| Palatal rugae | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Primary | Male | 65 | 293 | 4.51±0.92 | 0.034* |
| | Female | 65 | 280 | 4.20±0.81 | |
| Secondary | Male | 65 | 36 | 0.55±0.81 | 0.974 |
| | Female | 65 | 37 | 0.57±0.90 | |
| Fragmented | Male | 65 | 0 | 0 | 0.043* |
| | Female | 65 | 4 | 0.06±0.24 | |

*Statistical significance

On the right side of the palate of our samples, there were no significant differences in the number of primary, secondary, and fragmentary rugae between males and females. Both the primary and secondary rugae were more common in males than females, while the number of fragmentary rugae was almost equal in both sexes (P=0.98) (table 5).

In evaluating the shapes, wavy rugae were the most prevalent form in both sexes. In contrast, in females, this was followed by the curve and then straight rugae. In order of precedence, the total number of different rugae shapes in the overall male and female cases was wavy, curve, straight, diverging unification, converging unification, cross-link, and circular. The distribution of rugae shapes in males was observed (in descending order) as wavy, straight, curve, diverging unification, converging unification, cross-link, and circular. While in females it was observed as in the overall male and female patterns. The straight and diverging unification rugae were significantly more common in males than in females (P=0.01 and P=0.03, respectively). As shown in table 6, the least common form in both sexes was the circular rugae.

On the left side of the palate, only the distribution of the diverging unification shape of rugae showed a statistical significant difference (P=0.02) and it was more prevalent in males than females. Wavy shapes were most common in both sexes on the left side of the palatal followed by the curve, straight, diverging, converging, cross-link, and circular patterns (table 7).

On the right side of the palate, the distribution of rugae shapes in males and females had different patterns. The shape of the patterns in males was observed (in descending order) as wavy, straight, curve, diverging, converging, circular, and cross-link patterns. While in females it was wavy, curved, straight, diverging, converging, cross-link, and circular patterns. Straight rugae on the right side was significantly (P=0.01) more common in males (n=106) than in females (n=74) (table 8).

As shown in table 9, the rugae shape and length contributed to the discriminant function analysis. Three rugae shapes, namely curve (0.66), straight (0.56), and unification divergent (0.41) as well as the primary rugae length (0.67) had the greatest potential to determine sex identity among the Iranian population.

To determine the sex of an unidentified individual, the number of each type of rugae

**Table 5:** Distribution of palatal rugae length on the right side of the palate in males and females

| Palatal rugae | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Primary | Male | 65 | 290 | 4.46±1.21 | 0.504 |
| | Female | 65 | 279 | 4.29±1.04 | |
| Secondary | Male | 65 | 41 | 0.63±0.86 | 0.400 |
| | Female | 65 | 35 | 0.54±0.87 | |
| Fragmented | Male | 65 | 3 | 0.04±0.21 | 0.985 |
| | Female | 65 | 4 | 0.06±0.30 | |

**Table 6:** Distribution of different palatal rugae shapes in males and females

| Palatal rugae | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Straight | Male | 65 | 205 | 3.15±1.82 | 0.010* |
| | Female | 65 | 152 | 2.34±1.58 | |
| Circular | Male | 65 | 6 | 0.09±0.34 | 0.241 |
| | Female | 65 | 2 | 0.03±0.17 | |
| Curve | Male | 65 | 170 | 2.61±2.68 | 0.201 |
| | Female | 65 | 207 | 3.18±2.14 | |
| Wavy | Male | 65 | 229 | 3.52±1.72 | 0.928 |
| | Female | 65 | 228 | 3.51±1.71 | |
| Diverging | Male | 65 | 36 | 0.55±0.73 | 0.036* |
| | Female | 65 | 22 | 0.34±0.62 | |
| Converging | Male | 65 | 13 | 0.20±0.59 | 0.650 |
| | Female | 65 | 13 | 0.20±0.47 | |
| Cross-link | Male | 65 | 7 | 0.11±0.31 | 0.405 |
| | Female | 65 | 12 | 0.18±0.46 | |

*Statistical significance

**Table 7:** Distribution of different palatal rugae shapes on the left side of the palate in males and females

| Palatal rugae | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Straight | Male | 65 | 99 | 1.52±1.05 | 0.085 |
| | Female | 65 | 78 | 1.20±0.97 | |
| Circular | Male | 65 | 4 | 0.06±0.24 | 0.405 |
| | Female | 65 | 2 | 0.03±0.17 | |
| Curve | Male | 65 | 86 | 1.32±1.03 | 0.343 |
| | Female | 65 | 102 | 1.57±1.26 | |
| Wavy | Male | 65 | 112 | 1.72±1.15 | 0.996 |
| | Female | 65 | 108 | 1.66±0.92 | |
| Diverging | Male | 65 | 19 | 0.29±0.49 | 0.027* |
| | Female | 65 | 8 | 0.12±0.33 | |
| Converging | Male | 65 | 6 | 0.09±0.42 | 0.153 |
| | Female | 65 | 10 | 0.15±0.40 | |
| Cross-link | Male | 65 | 6 | 0.09±0.29 | 0.771 |
| | Female | 65 | 7 | 0.11±0.31 | |

*Statistical significance

**Table 8:** Distribution of different palatal rugae shapes on the right side of the palate in males and females

| Palatal rugae | | N | Rugae number | Mean±SD | P value |
|---|---|---|---|---|---|
| Straight | Male | 65 | 106 | 1.63±1.27 | 0.018* |
| | Female | 65 | 74 | 1.14±1.17 | |
| Circular | Male | 65 | 2 | 0.03±0.17 | 0.156 |
| | Female | 65 | 0 | 0 | |
| Curve | Male | 65 | 84 | 1.29±1.17 | 0.206 |
| | Female | 65 | 105 | 1.61±1.35 | |
| Wavy | Male | 65 | 117 | 1.80±1.12 | 0.931 |
| | Female | 65 | 120 | 1.85±1.13 | |
| Diverging | Male | 65 | 17 | 0.26±0.48 | 0.536 |
| | Female | 65 | 14 | 0.22±0.45 | |
| Converging | Male | 65 | 7 | 0.11±0.36 | 0.295 |
| | Female | 65 | 3 | 0.05±0.21 | |
| Crosslink | Male | 65 | 1 | 0.02±0.12 | 0.171 |
| | Female | 65 | 5 | 0.08±0.32 | |

*Statistical significance

**Table 9**: Discriminant function coefficients for rugae in the analysis

| Palatal rugae | | Unstandardized coefficients | Standardized coefficient | Classification function | |
|---|---|---|---|---|---|
| | | | | Male | Female |
| Length | Primary | 0.41 | 0.67 | 1.39 | 1.02 |
| | Secondary | 0.05 | 0.07 | -1.76 | -1.81 |
| | Fragmented | -0.80 | -0.26 | -3.74 | -3.01 |
| Shapes | Curve | -0.34 | -0.66 | 2.04 | 2.35 |
| | Circular | 0.84 | 0.23 | 3.41 | 2.64 |
| | Crosslink | -0.16 | -0.06 | 7.18 | 7.33 |
| | Wavy | -0.18 | -0.31 | 2.69 | 2.85 |
| | Straight | 0.33 | 0.56 | 3.22 | 2.91 |
| | Converge | -0.32 | -0.17 | 2.77 | 3.07 |
| | Diverge | 0.60 | 0.41 | 5.87 | 5.32 |

**Table 10:** Accuracy of the discriminant function analysis in the studied population

| | Male | Female | Total |
|---|---|---|---|
| Number of cases | 45/65 | 46/65 | 91/130 |
| % | 69.2% | 70.8% | 70% |

shape was multiplied by the corresponding unstandardized coefficient and then added to a constant (-3.081). If the obtained value was greater than the sectioning point (0.458-(0.458/2)=0), the individual was marked as male. But, if the value was less than the sectioning point, the individual was marked as female.[23] The method for calculating an unidentified sex (Z*) among the Iranian population was derived according to the following formula.

*Z*=-3.081+0.41(primary)+0.05 (secondary)-0.80 (fragmented)-0.34 (curve)+0.84 (circular)-0.16 (cross)-0.18 (wavy)+0.33 (straight)-0.32 (converge)+0.60 (diverge)*

The accuracy with which discriminant function can identify the sex of an individual is given in table 10.

## Discussion

The present cross-sectional study was carried out to evaluate the rugae patterns in a sample Iranian population and to compare the patterns between sexes. This approach can be used to differentiate sexes, particularly when other indicators are absent antemortem. Similar to most other studies, we also used the classification method given by Thomas and Kotze to differentiate the patterns of the palatal rugae. This method is considered as the most practical and easy to apply compared to other methods.[22] The fragmentary rugae of ≤3 mm were excluded from the study as it has been suggested that a simple classification system is more successful and reliable in rugae studies.[23] This classification is less complicated and clearer than other reported systems[6, 24] and does not have the issues related to complex patterns that might introduce additional observer bias.[5] Moreover, it has been widely used in similar published studies and thus allowed us to make more meaningful comparisons between our results and those conducted on other populations.[5, 6, 25]

The observation of rugae shapes using stone casts is a subjective study, relatively easy and less time-consuming,[1] and does not require complex instruments.[26] Consequently, no significant intra- or inter-observer errors were revealed in the current investigation.[27] The present study included the recording of rugae patterns from a sample group with a narrow age range of 17-25 years. The samples were selected among pre-orthodontic dental casts of individuals of Iranian origin who referred for orthodontic treatment at the Orthodontic Department of Shiraz University of Medical Sciences (Shiraz, Iran). To improve the accuracy of palatal rugae categorization, due diligence was exercised in the identification of various shapes and lengths of rugae morphologies on the stone casts.

The results did not show a considerable difference in the rugae lengths between sexes. Therefore, it was considered statistically insignificant. This correlates with the results of studies conducted by Nayak et al.[5] and confirmed the studies conducted by Kapali et al.[6] and Saraf et al.[28] In contrast, Dohke et al. showed an increase in the rugae lengths in females.[29] The total number of palatal rugae was slightly but insignificantly more in males (mean=10.25) compared to females (mean=9.78). This is inconsistent with reports on other populations.[5, 6, 18, 30-33] The number of primary rugae was found to increase in both sexes followed by the secondary rugae. Fragmented rugae were the least rugae pattern. This correlates with previous studies which demonstrated that the length remained the same in both sexes.[30] The number of primary and secondary rugae were more common in males, while the fragmentary rugae were more common in females. This is in line with a study conducted by Manjunath et al.[33] While no significant sex differences were observed regarding the rugae length on the right side of the palate, statistical significant differences were noted on the left side for the primary (P=0.03) and fragmentary (P=0.04) lengths. The primary rugae were more common in males, while the fragmentary rugae were more common in females on both sides. This result is not in agreement with the findings of Abdulmajid et al.[34] who observed no difference in rugae length of more than 10 mm among males and females. In addition, Fahmi et al.[25] showed that there was no significant difference in fragmented rugae within 5 to 10 mm length among males and females. Bajracharya et al.[35] conducted a study on the Nepalese population to determine an association between sex and the pattern and number of palatal rugae. They found no statistically significant difference in the palatal rugae number and pattern among sex groups. In the present study, for both sexes, there was no significant bilateral asymmetry in

any of the rugae lengths on the right side of the palate, while on the left side, only the secondary rugae showed insignificant differences.

The distribution of different palatal rugae shapes in males and females showed that, in terms of the overall sample, the most prevalent palatal rugae patterns in descending order were wavy, curve, straight, diverging unification, converging unification, cross-link, and circular. There is a general agreement among studies on various populations that wavy and curved configurations are the most prevalent patterns of palatal rugae.[5, 27, 36] Wavy and curved morphologies were found to comprise 45.85% and 24.41% of the total rugae, respectively, in Indian Odisha subjects;[36] 55.8% and 23.2%, respectively, in Australian Aborigines;[6] 40.6% and 25.8%, respectively, in Caucasian individuals;[6] 34.47% and 44.71%, respectively, in Western Indians; 38.33% and 26.83%, respectively, in Southern Indians;[6] 29.38% and 35.40%, respectively, in Egyptians; and finally 29.38% and 35.40%, respectively, in Saudi children.[27] These findings are in agreement with the present study which showed that the wavy and curved palatal rugae configurations were 39% and 29% of the total rugae, respectively.

Taken together, these studies suggest that wavy and curved shapes represent the most frequent palatal rugae shapes across a range of different ethnicities.[6,36] In the present study, the cross-link rugae comprised 14.96% of the total number of palatal rugae shapes which was higher than that of the Egyptian individuals (5.31%). Moreover, the cross-link rugae were not found in Saudi individuals,[26] Andhra Pradesh and Odisha Indian individuals,[18] nor in Australian Aborigines and Caucasian cohorts.[6] The frequency of the straight shape (27%) in the present study was higher than that of the Caucasians (15.2%),[6] Egyptians (20.71%) and Saudis (19.71%),[27] Odisha Indians (6.69%),[36] and Australian Aborigines (3.6%);[6] however, lower than that of the Andhra Pradesh Indians (37.3%).[36]

In Libyan individuals the frequency of diverging unification was 9.06%, but the converging unification and circular palatal rugae shapes were not observed. In Egyptian individuals the palatal rugae with diverging and converging unification represented 2.64% and 4.07% of the total rugae, respectively; in Saudis 4.84% and 0%, respectively;[27] in Australian Aborigines 13.9%; in Caucasians 15.6%;[6] in Andhra Pradesh (India) 4.16%; and in Odisha (India) 16.23%.[36]

Circular palatal rugae were not observed in the present study. However, it was reported at 2.48% of the total rugae in Egyptians, 1.25% in Saudis,[27] 3.6% in Australian Aborigines, and 2.9% in Caucasians.[6] It has been shown that certain palatal rugae patterns and shapes might be unique to specific populations.[18, 27-37] Consistent with this finding, it was observed that some types of palatal rugae morphology were rare or absent in other ethnicities.

In terms of length, palatal rugae are classified into three categories, namely primary, secondary, and fragmentary rugae. Based on our analysis, the distribution of these palatal rugae was practically equal among males and females. The primary rugae were mainly observed in males (8.97±1.74) and in females (8.49±1.53) followed by the secondary rugae in both sexes (1.19 and 1.11, respectively) and fragmentary rugae in males (0.04) and in females (0.12). These results were in line with those reported by previous studies.[1, 8, 24, 27] Significant differences were observed between sexes and the number of primary (P=0.03) and fragmentary (P=0.04) rugae on the left side of the palate. While the primary rugae were more common in males, the fragmentary rugae were more common in females (n=4) compared to males (n=0). Depending on the length of the palatal rugae, straight and diverging unification rugae were significantly more common in males than in females (P=0.01 and P=0.03, respectively).

In the present study, it was observed that all the rugae patterns were unique to each dental cast without any similarities to other casts. Therefore, the individuality of these patterns was concluded.[7] Considering the low operational cost, simplicity, and reliability of palatal rugoscopy, the application of this technique has clear advantages in forensic identification.[38, 39] Palatal rugae patterns provide adequate characteristics to differentiate sexes.[7, 23, 26, 28, 37] These patterns are proven to remain identical before and after orthodontic treatment[40] and persist stability even after the completion of growth.[33] Consequently, the use of palatal rugae patterns in forensic medicine is emerging as a reliable application. Various studies have indicated a specific association between palatal rugae patterns and racial and geographical variations as well as its applicability for gender differentiation.[26, 28, 30, 41-44]

The main limitation of the present study was related to the low sample size (65 individuals of each sex) and its confined location (Shiraz, Iran). Consequently, further studies with larger sample size and participants from other parts of the country are required for a better comparison. Since the findings of the present study are preliminary, nationwide research projects with larger groups are required to obtain a clear picture of the morphological variation of palatal

rugae in the Iranian population. It is also worth to examine cohorts from the neighboring countries to allow a comparison between different populations in the same study.[33]

## Conclusion

The results of the present study showed that there was no statistical significance in the total number of rugae in males and females. However, with respect to length, significant differences were observed between the sexes as well as the number of primary rugae in males and fragmentary rugae in females on the left side of the palate. There was also a significant difference in the shapes of rugae that showed a higher number of the straight type in males and diverging unification in females. Evidently, palatal rugae patterns offer sufficient characteristics to discriminate between the sexes and to substantiate the assumption of the uniqueness of palatal rugae and therefore could serve as a tool in forensic identification. Discriminant function analysis enabled sex identification with an accuracy of 70%. Further studies with a larger sample size could substantiate the results of the present study.

## Acknowledgment

The authors would like to thank the Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences (Shiraz, Iran) for providing the pre-orthodontic dental casts. We also would like to express our gratitude to Dr. Vosoghi (Oral Health and Community Dentistry Department, Shiraz Dental School) for his valuable contribution towards the statistical analysis of data. The present study was performed in the context of D.M.D degree requirements of A.R. Malekzadeh.

**Conflict of Interest:** None declared.

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