DOI: 10.30476/DENTJODS.2019.44556

Original Article

Characteristics of Palatal Rugae Patterns as a Potential Tool for Sex Discrimination in a Sample of Iranian Children

Fatemeh Pakshir [1], Shabnam Ajami [2], Hamid Reza Pakshir [2], Ali Reza Malekzadeh [1]

[1] Student Research Centre, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.
[2] Orthodontic Research Center, Dept. of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran.

KEY WORDS
Palatal Rugae;
Rugae Pattern;
Forensic Identification;
Sex Assessment;
Iranian Children;
Discriminant Function Analysis;

Received October 2017;
Received in Revised form December 2017;
Accepted May 2018;

ABSTRACT

Statement of the Problem: Palatal rugae have been considered equivalent to fingerprints, as they are unique to each individual. It has been shown that palatal rugae are associated with specific racial groups and are known to aid sex identification. Due to the lack of any published data on palatal rugae morphology on Iranian children, the present study was performed.

Purpose: The present study aimed to investigate differences in the morphology of individual palatal in a sample of Iranian children. Additionally, it is intended to develop discriminant function to identify sex, based on rugae morphology.

Materials and Method: A total of 120 pre-orthodontic casts were evaluated for different rugae patterns using the Thomas and Kotze classification. The casts were equally distributed between sexes with an age range of 6-12 years. Rugae length, shape, and associated morphology were recorded and the independent t-test and Chi-square test were used to compare the mean and relationship between the attributes. The discriminant function analysis was applied to the data in order to determine the applicability of palatal rugae patterns as an aid for sex identification.

Results: While the total rugae count showed an insignificant difference between the males and females, the rugae count on the right side of the palates showed a significant difference (p= 0.046). The primary rugae were most common in both sexes, followed by the secondary and fragmentary rugae. The most prevalent rugae shape between both sexes was the wavy rugae followed by the curve and straight shapes in males and the straight and curve shapes in females. A significant difference was observed in the number of the curve rugae between the sexes. Discriminant function analysis allowed sex differentiation with an accuracy of 60.8%.

Conclusion: Palatal rugae shapes are unique to each individual and could be used as a potential tool for sex identification. Further research on a larger sample is required to fully confirm the application of this method (e.g. in forensic medicine) as a complementary technique for sex identification.

Corresponding Author: Ajami Sh., Orthodontic Research Center, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran. Tel: +98-7136263193-4 Email: dr.ajami.sh@gmail.com

Cite this article as: Pakshir F., Ajami Sh., Pakshir HR., Malekzadeh AR. Characteristics of Palatal Rugae Patterns as a Potential Tool for Sex Discrimination in a Sample of Iranian Children. *J Dent Shiraz Univ Med Sci.,* March 2019; 20(1): 1-9.

Introduction

In the area posterior to the incisive papilla in both sides of the median palatal raphe are the transverse ridges called "palatal rugae" or "rugae palatinae." [1-2] Palatal rugae are the transverse fold of mucosa, which is recorded in maxillary impression and can be observed in the maxillary cast fabrication. [3] These asymmetric bilateral anatomical elevations of variable prominence on the roof of the hard palate are highly individualistic and non-identical even among twins. [4-5] The shape of

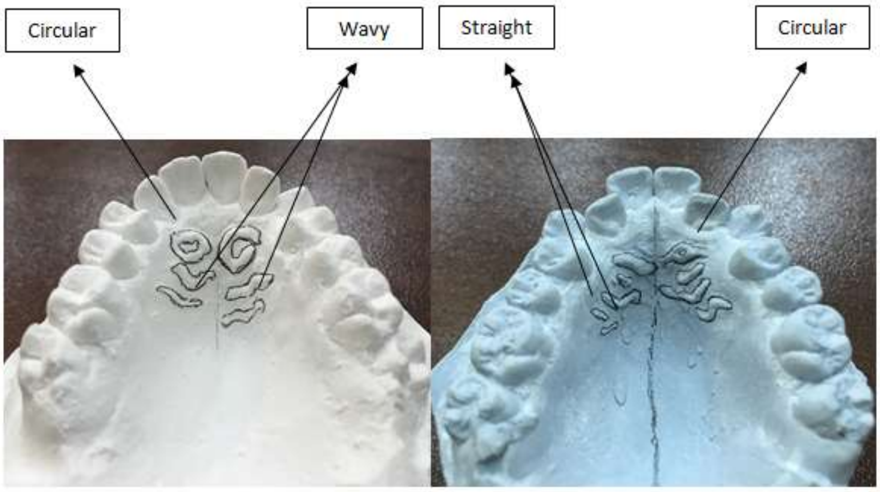

Figure 1: Maxillary upper stone casts of Iranian children showing dissimilar rugae shapes for different individuals

palatal rugae is stable and consistent throughout the life after the completion of growth. Palatal rugae can resist the incidents of fire and significant trauma due to a proper protection by the lips, cheeks, tongue, buccal fat pad, and teeth. They can also resist decomposition up to seven days. [6-8]

Palatal rugae are formed from the lateral membrane of the incisive papilla in the third month of intrauterine life and are present from birth in the anterior third of the palatal mucosa. [3-4] They show various configurations and are completely unique in every individual due to their design and structure, similar to fingerprints. [9]

The length of palatal rugae increases during normal growth, but their orientation remains the same throughout the lifetime of a person. [10] However, local alteration in the position and direction of palatal rugae might be produced by tooth extraction, finger sucking during childhood and orthodontic treatment, which incur consistent pressure on the tooth and alveolar process. [11-12] In forensic science, the uniqueness of palatal rugae in each individual has been recognized as a potential source of identification of a person. Palatal rugoscopy was primarily proposed by Troban Hemaso in 1932. [13-14]

Since then, various other classifications have been proposed among which Thomas and Kotze [15] classification is the most popular and widely used in many studies. According to the classification by Lysell *et al.* [1], the length of palatal rugae is categorized into three groups defined as Primary: >5mm, Secondary: 3-5mm, and Fragmented: <3 mm. Rugae less than 2 mm are disregarded. Furthermore, the shape of individual rugae, as classified by Thomas and Kotze, [15] are shown in Figure 1 and 2 and described as (1) Curved; a crescent form with a mild curve, (2)Wavy: a slight curvature at

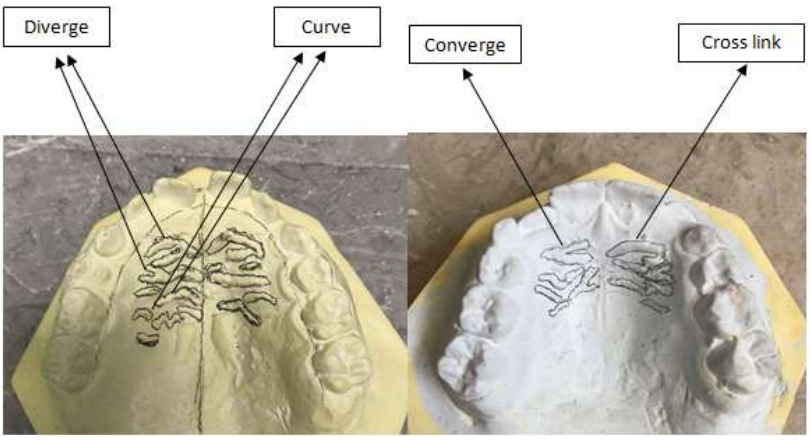

Figure 2: Maxillary upper stone casts showing different unification rugae shapes

DOI: 10.30476/DENTJODS.2019.44556

the origin or termination of curved rugae, (3) Straight: they appear straight from their origin to termination of rugae, (4) Circular: a definite continuous ring of rugae, and (5) Unification: when two rugae are joined at their origin or termination. [15]

Unifications, in which two rugae start from the same origin but immediately diverged, are classified as diverging. Rugae with different origins joined on their lateral segment are classified as converging.

It has been claimed that the shape, length, width, and direction of palatal rugae vary significantly amongst different populations and individuals. [15]

Moreover, differences in shape and orientation between the right- and left-side of the palatal rugae was demonstrated, which results in an asymmetrical rugae configuration in most individuals. [13, 16] Considering their physiological function, palatal rugae have a significant role in swallowing, prevention of food loss from the mouth, taste perception, and involvement in food crushing. [17] They also assist speech and suction in children. [18] Due to the specific features of palatal rugae, including uniqueness, post-mortem resistance, and stability, they can be useful in forensic identification.

In addition, rugae pattern, which shows to be unique for different racial groups, can facilitate population identification. [14, 19-20] In addition, there is an agreement amongst researchers that the features of palatal rugae (i.e. length and shape) might represent a specific population. [11, 16-17] Due to the lack of any published data on palatal rugae morphology among the Iranian population, the present study aimed to evaluate the morphology of palatal rugae in a sample of Iranian children. The main objective was to provide preliminary data to assess possible sexual differences in the palatal rugae from, length, the number of primary and secondary, and fragmented rugae. Additionally, we aimed to compare the results with those obtained from other populations.

Materials and Method

In the present study, pre-orthodontic maxillary casts of children that referred to the Orthodontics Department, School of Dentistry, Shiraz University of Medical Sciences (Shiraz, Iran) were investigated. The samples were from 120 patients (60 males and 60 females) in the age group of 6-12 years. All children were healthy according to their medical history. The dental casts were coded by the administrative staff to obscure personal information of the patients.

The cast of individuals with congenital anomalies, previous history of orthodontic treatment, bony and soft tissue protuberances, and areas of active lesions, deformity, and scars were excluded from the present study.

As the inclusion criteria in selecting casts, those maxillary arch casts that did not have air bubble or voids, particularly at the anterior third of the palate, were selected. The exclusion criteria were damaged casts and casts on which rugae patterns were not detectable (i.e. without any discrepancies or voids). The palatal rugae were highlighted with a sharp graphite pencil under adequate light and the patterns of the rugae were determined. The number of the rugae on either side of the midline was counted. A digital Vernier caliper, calibrated to 0.01 mm, was used to measure and record the length under magnification; starting point of rugae at mid-palatine raphe to the endpoint of rugae transversely. In case of circular shape, the maximum diameter was taken into consideration.

The number, shape, unification, and length of the rugae between either sides of the palate (left, right) for both sexes were compared for the total number of rugae, number of primary rugae, predominant shape, and the unification of rugae. The counting of rugae and their patterns were performed by two independent examiners who were adequately trained and calibrated to ensure uniform elucidations and concordant registration.

Statistical Analysis

The two-sample t-test and Chi-square test were used to compare the means and the relationship between variables. A significance level of 5% was considered as the critical value. In addition, the obtained data were used for discriminant function analysis to determine the applicability of palatal rugae pattern as an indicator for sex identification.

Results

Based on Kappa statistics, the inter-examiner reliability for the assessment of palatal rugae was found to be 89%. The prevalence of different rugae lengths and shapes in the studied population is presented in Table 1.

Table 1: Descriptive analysis of the total number of rugae

Palatal rugae	N	Rugae number	Mean±SD
Total number	120	1,139	9.49±1.86
Primary	120	1,014	8.43±1.54
Secondary	120	118	0.98±1.21
Fragmented	120	7	0.05±0.23
Straight	120	307	2.56±1.69
Wavy	120	409	3.41±1.54
Curved	120	300	2.50±1.62
Diverge	120	74	0.62±0.73
Converge	120	32	0.25±0.54
Cross link	120	15	0.12±0.35
Circular	120	2	0.01±0.13

Table 2: Distribution of palatine rugae numbers in males and females

Palatal rugae	Sex	N	Rugae number	Mean±SD	*p* Value
Right	Male	60	298	4.97±1.13	0.046*
	Female	60	277	4.62±1.09	
Left	Male	60	285	4.75±1.19	0.559
	Female	60	279	4.65±0.97	
Total	Male	60	583	9.72±1.90	0.055
	Female	60	556	9.27±1.79	

*Significant difference

Table 3: Distribution of rugae length in males and females

Palatal rugae length	Sex	N	Rugae number	Mean±SD	*p* Value
Primary	Male	60	516	8.58±1.64	0.194
	Female	60	498	8.28±1.43	
Secondary	Male	60	61	1.02±1.06	0.318
	Female	60	57	0.95±1.35	
Fragmented	Male	60	6	0.10±0.30	0.052
	Female	60	1	0.02±0.13	

The primary rugae were predominant compared to the secondary and fragmented rugae. Considering the shapes, the wavy rugae were the most prevalent form. The distributions of palatal rugae numbers are described in Table 2. Larger number of rugae was reported in males in comparison to females without any statistical significance (p= 0.055). On the right side of the palate, the number of rugae was significantly more in male comparing with females (p= 0.04). However, on the left side, while the number of rugae was higher in males but was not significant.

No significant asymmetry in all rugae lengths was noted in both sexes and the primary rugae on the left side and the secondary rugae on the right side were comparable and similar.

Considering the rugae length (Table 3), the mean number of primary, secondary, and fragmented rugae was greater in males than that of females. However, the mean between sexes did not show significant differences (p> 0.05). As shown in Tables 4 and 5, differences in rugae length between left and right side, for both sexes were assessed.

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

Palatal rugae (left side)	Sex	N	Rugae number	Mean±SD	*p* Value
Primary	Male	60	255	4.23±0.91	0.984
	Female	60	256	4.27±0.92	
Secondary	Male	60	27	0.45±0.67	0.394
	Female	60	23	0.38±0.71	
Fragmented	Male	60	3	0.05±0.22	0.081
	Female	60	0	0	

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

Palatal rugae (right side)	Sex	N	Rugae number	Mean±SD	*p* Value
Primary	Male	60	261	4.35±1.09	0.108
	Female	60	241	4.02±0.87	
Secondary	Male	60	34	0.57±0.89	1
	Female	60	34	0.57±0.89	
Fragmented	Male	60	3	0.05±0.22	0.311
	Female	60	1	0.02±0.13	

Considering the rugae shape (Table 6), the wavy rugae were the most prevalent form in both sexes. However, the distribution frequency of other rugae shapes differed between male and females. Except for the curved shapes that significant differences between sexes were demonstrated (p= 0.049), other shapes showed insignificant differences between males and females (p> 0.05).

The least common shape in both sexes was the circular shape. Females had a higher number of wavy and cross-link rugae compared to males. However, males tended to have more curved rugae.

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

Palatal rugae Shapes	Sex	N	Rugae number	Mean±SD	*p* Value
Straight	Male	60	153	2.55±1.69	0.887
	Female	60	154	2.57±1.70	
Circular	Male	60	1	0.02±0.13	1
	Female	60	1	0.02±0.13	
Curve	Male	60	168	2.80±1.67	0.049*
	Female	60	132	2.20±1.53	
Wavy	Male	60	199	3.32±1.67	0.496
	Female	60	210	3.50±1.41	
Diverge	Male	60	38	0.63±0.74	0.758
	Female	60	36	0.60±0.74	
Converge	Male	60	19	0.32±0.57	0.353
	Female	60	13	0.22±0.49	
Cross link	Male	60	5	0.08±0.28	0.248
	Female	60	10	0.17±0.42	

*Significant difference

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

Palatal rugae (left side)	Sex	N	Rugae number	Mean±SD	*p* Value
Straight	Male	60	72	1.20±1.09	0.859
	Female	60	70	1.17±1.06	
Circular	Male	60	0	0	0.317
	Female	60	1	0.02±0.13	
Curve	Male	60	87	1.45±1.14	0.342
	Female	60	76	1.27±1.12	
Wavy	Male	60	97	1.06±1.06	0.477
	Female	60	104	1.73±0.95	
Diverge	Male	60	18	0.30±0.50	0.270
	Female	60	12	0.40±0.40	
Converge	Male	60	9	0.15±0.36	1
	Female	60	9	0.15±0.36	
Cross	Male	60	2	0.18±0.18	0.142
	Female	60	7	0.12±0.37	

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

Palatal rugae (right side)	Sex	N	Rugae number	Mean±SD	*p* Value
Straight	Male	60	81	1.35±1.25	0.631
	Female	60	84	1.40±1.17	
Circular	Male	60	1	0.02±0.13	0.317
	Female	60	0	0	
Curve	Male	60	81	1.35±1.02	0.018*
	Female	60	56	0.93±0.97	
Wavy	Male	60	102	1.70±1.12	0.695
	Female	60	106	1.77±0.98	
Diverge	Male	60	20	0.33±0.60	0.427
	Female	60	24	0.40±0.59	
Converge	Male	60	10	0.17±0.42	0.074
	Female	60	4	0.07±0.31	
Cross	Male	60	3	0.05±0.22	1
	Female	60	3	0.05±0.22	

*Significant difference

Comparable numbers of straight and diverging unification rugae were observed between males and females. The bilateral differences in rugae shapes in both sexes are summarized in Tables 7 and 8. A significant difference in the shape was found on the right side of the palate in terms of the number of curve patterns in males, which was higher than that of females (*p*= 0.018). Besides, on the left side of palate, the frequency of the rugae shapes was similar in both sexes.

In terms of the three predominant forms, the sequence of rugae shapes on the right side was not similar to the left side. The rugae shape and length were used in the discriminant function analysis. As shown in the standardized coefficients column of Table 9, it was observed that variables such as the fragmented rugae length and curve rugae shape have the greatest potential to determine sex identity among the Iranian children. To determine the gender of an unidentified case, the number of each type of rugae shape is multiplied by the corresponding unstandardized coefficient and then added by a constant (-2.807). If the obtained value is greater than the sectioning point (0.347-0.347)/2=0), the individual is tagged as male. Otherwise, if the value is less than the sectioning point, the individual is tagged as female (Table 10). [21]

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

Palatal rugae variables		Unstandardized coefficients	Standardized coefficients	Classification function	
				Male	Female
Length	Primary	0.18	0.28	1.61	1.48
	Secondary	-0.09	-0.14	-1.08	-1.02
	Fragmented	2.55	0.59	1.23	0.54
Shape	Curve	0.42	0.67	2.98	2.68
	Circular	1.51	0.19	14.05	13
	Cross link	-0.80	-0.28	4.07	4.62
	Wavy	0.04	0.06	3.90	3.87
	Straight	-0.07	-0.12	2.24	2.29
	Converge	1.02	0.56	6.64	5.93
	Diverge	0.25	0.18	6.28	6.11

Table 10: Function at group centroids

Sex	Function 1
F	-0.347
M	0.347

Table 11: Accuracy of the discriminant function analysis in the studied population

	Male	Female	Total
Number of cases	34/60	39/60	73/120
%	56.7%	65%	60.8%

Hence, the method for calculating an unidentified sex (Z*****) among the Iranian children is derived according to the following formula:

Z*****= -2.807+0.18(primary)- 0.09(secondary) +2.55 (fragmented)+0.42(curve)+1.51 (circular) -0.80 (cross)+ 0.04 (wavy) -0.07 (straight)+ 1.02 (converge)+ 0.25 (diverge)

The accuracy with which the discriminant function can identify the sex is given in Table 11.

Discussion

The present cross-sectional observational study was carried out to investigate rugae patterns in a sample of Iranian children. The rugae patterns between males and females were compared with the aim of developing an alternative method for sex identification, particularly when other indicators are missing ante mortem. The number, shape, and length of the primary, secondary, and fragmented rugae in males and females were assessed to determine a possible statistical difference. In this regard, we ensured excellent intra-operator agreement between the two assessors.

Thomas and Kotze [15] classification is the most popular and widely used in many studies. [14, 19-20] This classification method is shown to be the most practical and easy to apply compared with other methods. [2] Hence, in the present study, we also used the Thomas and Kotze [15] classification to differentiate rugae patterns. Moreover, the likelihood of description accuracy is enhanced by using stone casts. [22]

The number of palatal rugae was slightly more in males (mean=9.72) than females (mean=9.27), which was inconsistent with various reports on other populations. [5, 10, 14, 21] Our analysis showed that the distribution of the primary rugae was predominant in both males (88.5%) and females (89.5%). While, no significant difference in the total number of palatal rugae was shown between sexes, significantly higher number of rugae on the right side of the palate in male was reported in comparison to females (p= 0.04). Our observation agrees with some studies [26-27] but differs with others. [14, 28-31] In a Libyan cohort study [31], it was shown that the number and shape of the paired palatal rugae were similar to the results yielded by Shetty *et al.* [20]

The analysis of the number of primary rugae in Australian aborigines failed to reveal any significant differences between the two sides of the palate or between genders. [14] This observation differs with the result of the present study a significantly greater number of rugae was found on the right side of the palate in males. In contrary to our results, Dhoke *et al.* [27] observed fewer palatal rugae on right side. It was suggested that this could be the result of regressive evolution dominating the right side of the palate. [27]

The analysis of the rugae shapes of all subjects in the present study showed that the three most prevalent shapes in descending order were the wavy (36%), straight (27%) and curve (26%) rugae, which comprised 89% of the total number of rugae. In a Libyan population, the most prevalent palatal rugae patterns, in decreasing order, were the wavy, curve, cross link, and straight rugae, respectively. There is a general agreement among various studies carried out in different populations that the wavy and curved configurations are the most prevalent palatal rugae morphology. [29, 33]

The wavy and curved palatal rugae were found to comprise 45.85% and 24.41% of the total rugae, in Indian Odisha subjects [33], 55.8% and 23.2%, in Australian aborigines [17], 40.6% and 25.8%, in Caucasian individuals [14], 34.47% and 44.71%, in Western Indians 38.33% and 26.83%, in Southern Indians [29], 29.38% and 35.40%, in Egyptians, [30] 38% and 35.40%, in Saudi children [30], and 38.01% and 24.39%, in Libyan children, respectively. [31]

These findings are to a certain extent in agreement with the results of the present study whereby the wavy and curve palatal rugae configurations were 36% and 26% of the total number of rugae, respectively. However, the frequency of the straight rugae shape (27%) was slightly higher than the curve rugae configuration (26%).

The frequency of the straight rugae pattern (27%) in the present study was markedly higher than that of the Odisha Indians (6.69%), [6] Australian aborigines (3.6%), [14] Caucasians (15.2%), [14] and Libyan children (14.28%). [31] However, it was slightly higher than that of the Egyptians (20.71%) and Saudis (19.71%). [30] In contrary, the frequency of the straight rugae pattern was markedly lower than that of the Andhra Pradesh Indians (37.3%). [33] In the present study, the frequency of diverging unification, converging unification, cross link, and circular was demonstrated to be 6.76%, 2.80%, 1.31%, and 0.17%, respectively.

The frequency of diverging unification was found to be 9.06% in Libyan subjects, while the converging unification and circular palatal rugae were not observed. [31] The circular palatal rugae were the least observed (two cases in the total number of subjects) in the present study. This pattern, while not observed in Libyan subjects, [31] was reported at 2.48% of the total rugae in Egyptians and 1.25% in Saudis, [30] 3.6% in Australian aborigines and 2.9% in Caucasians. [14] The frequency of the cross-link rugae comprised 1.31% of the total number of palatal rugae.

This percentage was markedly less than that of the Libyan subjects (14.96%) [31] and Egyptian (5.31%), [30] while the cross-link rugae were not found in Saudi subjects, [30] Andhra Pradesh and Odisha Indian individuals, [6] Australian aborigines and Caucasian cohorts. [14] The above analysis implies that certain pala-

DOI: 10.30476/DENTJODS.2019.44556

tal rugae morphology and shapes may be particular to specific population. [1, 4, 6, 16, 20, 27-29, 31, 34] Moreover, it is also observed that some types of palatal patterns are rare or absent in other ethnicities. [31]

Many studies have evaluated the difference in the form of palatal rugae in different populations as well as in both sexes. [13, 15, 19, 33] Differences in rugae shapes have been shown in relatively similar but different population groups, indicating that rugae shape may be specific to racial groups. [14, 20, 34]

Palatal sides comparison of the rugae morphology revealed that such significant difference is due to the higher number of curve rugae on the right side of males than that of females (p=0.018). Some studies reported no sex differences, [14, 32] while others reveal a difference. [27-28] Among the unification patterns, diverging pattern was reported more in both sexes than the converging pattern.

This is consistent with the previous study performed on the Libyan children. [31] In contrast, comparison in the rugae shapes showed statistically significant sex dimorphism in unification type in three South Indian population studies. [35-36] The results of the present study showed that the prevalence of the wavy and straight rugae patterns was more than that of the other rugae patterns.

This finding is in contrast with some other studies, such as the report by Kapali *et al.* [14] as the prevalence of curve and wavy rugae patterns was more than that of straight and circular patterns. They also found insufficient differences in the mean length of rugae between males and females.

However, on average, females had a higher number of rugae and the diverging unification pattern showed a significant prominence on the left side. Saraf *et al.* [34] did not find any differences in the number of primary rugae of males and females. However, our results showed a significant difference in the number of rugae between the sexes on the right side of the palate.

Our results conform to those reported by Dohke *et al.* [27] who indicated that Japanese females had fewer rugae than males. This might be because the secondary and fragmentary rugae were not included by Saraf *et al.*, [34] whereas its inclusion in our study as well as the study by Dohke *et al.* [27] has resulted in sex differentiation. The result of the present study has shown a significant difference in the frequency and configuration of palatal rugae between the sexes. Consistent with our results, other research studies performed on Japanese and Saudi children (>10 years old), indicated significant differences in the morphology and percentage of palatal rugae between males and females. [28, 30] In contrary, two other studies performed on adult subjects (>20 years old) in Japanese and Saudi populations did not reveal any significant difference in the frequency and configuration of palatal rugae between sexes. In a study by Nayak *et al.* [29] on the population differentiation using rugae shape, they mentioned that discrete variables such as rugae shape are more appropriate than continuous variables such as rugae length.

This is in line with our finding whereby no significant difference was observed in the length of the rugae between sexes while a difference was noted in the rugae shape. This entails that distinct variables are also better suited for sex differentiation.

Conclusion

Based on the observed differences in palatal rugae length and shape between males and females in the present study, it is concluded that palatal rugae patterns provide an adequate number of characteristics to discriminate between the sexes.

This finding substantiates the hypothesis that palatal rugae are unique and can be used in forensic medicine as a complementary technique for sex identification. The findings of the present study should be viewed as preliminary. Additional studies are required (on larger groups across the whole country) to draw a clearer picture of the morphological variation in palatal rugae pattern in Iranian children.

Acknowledgments

The authors thank the Vice-Chancellery of Shiraz University of Medical Science for supporting this research (Grant# 14099). This manuscript is based on the thesis by Dr. Fatemeh Pakshir. We would also like to thank the Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences (Shiraz, Iran) for providing the pre-orthodontic dental casts. The authors also thank Dr. Vosoughi of the Center for Research Improvement of the school of Dentistry for statistical analysis.

Conflict of Interest

None declared

References

[1] Lysell L. Plicae palatinae transversae and papilla incisiva in man; a morphologicand genetic study. Acta Odontol Scand. 1955; 13(Suppl. 18): 5-137.

[2] Thomas CJ, Kotze TJ, Van der Merwe CA. An improved statistical method for the racial classification of man by means of palatal rugae. Arch Oral Biol. 1987; 32: 315-317.

[3] Sivaraj A. Significance of palatal rugae in orthodontics. J Orofac Res.2013; 3: 202–209.

[4] Salzman JA. Review of Lysell L. Plica palatinae transversae and papillae incisiva in man - amorphologic and genetic study. Am J Orthod. 1955; 41: 879-880.

[5] Indira A, Gupta M, David MP. Usefullness of palatal rugae patterns in establishing identity: Preliminary results from Bengaluru city, India. J Forensic Dent Sci. 2012; 4: 2-5.

[6] Acharya AB, Sivapathasundaram B. Forensic odontology. In: Rajendran R, Sivapathasundaram B, editors. Shafer's Textbook of Oral Pathology. 5th ed. New Delhi, India: Elsevier Publications; 2007. p. 886.

[7] Muthusubramanian M, Limson KS, Julian R. Analysis of rugae in burn victims and cadavers to simulate rugaeidentification in cases of incineration and decomposition. J Forensic Odontostomatol. 2005; 23: 26-29.

[8] Segelinck SL, Goldstein L. Forensic application of palatal rugae in dental identification. Forensic Exam Spring. 2005; 14: 44-77.

[9] Winslow JB. Expositio anatomica structurae corporis humani. Available at: https://catalog.hathitrust.org/ Record/ 009275727

[10] Hermosilla VV, San Pendro VJ, Cantin LM, Suazo GI, Ruga P. Systematic analysis of its shape and dimensions for use in human identification. Int J Morphol. 2009; 27: 819–825.

[11] Peavy DC Jr, Kendrick GS. The effects of tooth movement on the palatine rugae. J Prosthet Dent. 1967; 18: 536-542.

[12] Limson KS, Julian R. Computerized recording of the palatal rugae pattern and an evaluation of its application in forensic identification. J Forensic Odontostomatol. 2004; 22: 1-4.

[13] Patil MS, Patil SB, Acharya AB. Palatine rugae and their significance in clinical dentistry: a review of the literature. J Am Dent Assoc. 2008; 139: 1471-1478.

[14] Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian aborigines and Caucasians. Aust Dent J. 1997; 42: 129-133.

[15] Thomas CJ, Kotze TJ. The palatal ruga pattern in six southern African human populations, partI: A description of the populations and a method for its investigation. J Dent Assoc S Afr. 1983; 38: 547-553.

[16] van der Linden FP. Changes in the position of posterior teeth in relation to ruga points. Am J Orthod. 1978; 74: 142-161.

[17] Buchtova M, Tichy F, Putnova I, Misek I. The development of palatal rugae in the European pine vole, Microtus subterraneus (Arvicolidae, Rodentia). Folia Zool. 2003; 52: 127-136.

[18] Thomas CJ, Van Wyk CW. Elastic fibre and hyaluronic acid in the core of human palatal rugae. J Biol Buccale. 1987; 15: 171-174.

[19] Thomas CJ, Kotze TJ. The palatal rugae pattern in six South African human populations. Part –II. Inter racial differences. J Dent Assoc S Afr. 1983; 38: 166–172.

[20] Shetty SK, Kalia S, Patil K, Mahima VG. Palatal rugae pattern in Mysorean and Tibetan populations. Indian J Dent Res. 2005; 16: 51-55.

[21] Gadicherla P, Saini D, Bhaskar M. Palatal rugae pattern: An aid for sex identification. J Forensic Dent Sci. 2017; 9: 48-49.

[22] Sognnaes RD. Forensic stomatology (third of three parts). N Engl J Med. 1977; 296: 197-203.

[23] Gautam N, Patil SG, Krishna RG, Agastya H, Mushtaq L, Kumar KV. Association of Palatal Rugae Pattern in Gender Identification: An Exploratory Study. J Contemp Dent Pract. 2017; 18: 470-473.

[24] Caldas IM, Magalhães T, Afonso A. Establishing identity using cheiloscopy and palatoscopy. Forensic Sci Int. 2007; 165: 1-9.

[25] Gillespie TH, Brannon RB, Grayson FW, Gardner JD. Dental identification of remains from the 23 October 1983 bombing of the U.S. Marine Headquarters, Beirut, Lebanon. Mil Med. 1985; 150: 635-639.

[26] Fahmi FM, Al-Shamrani SM, Talic YF. Rugae pattern in Saudi population sample of males and females. Saudi Dental J. 2001; 13: 92-95.

[27] Dhoke M, Osato S. Morphological study of the palatal rugae in Japanese. Bilateral difference in the regressive

evolution of the palatal rugae. Jpn J Oral Biol. 1994; 36: 126–140.

[28] Kashima K. Comparative study of the palatal rugae and shape of the hard palatal in Japanese and Indian children. Aichi Gakuin Daigaku Shigakkai Shi. 1990; 28(1 Pt 2): 295-320.

[29] Nayak P, Acharya AB, Padmini AT, Kaveri H. Differences in the palatal rugae shape in two populations of India. Arch Oral Biol. 2007; 52: 977-982.

[30] Abdellatif AM, Awad SM, Hammad SM. Comparative study of palatal rugae shape in two samples of Egyptian and Saudi children. Pediatric Dent J. 2011; 21: 123–128.

[31] Abdulmajid Z, Bugaighis I. Evaluation of the Morphology of Palatal Rugae in Libyan School Children. J Dent Res. 2015, 2: 024.

[32] Hauser G, Daponte A, Roberts MJ. Palatal rugae. J Anat. 1989; 165: 237-249.

[33] Rath R, Reginald BA. Palatal rugae: An effective marker in population differentiation. J Forensic Dent Sci. 2014; 6: 46-50.

[34] Saraf A, Bedia S, Indurkar A, Degwekar S, Bhowate R. Rugae patterns as an adjunct to sex differentiation in forensicidentification. J Forensic Odontostomatol. 2011; 29: 14-19.

[35] Bharath ST, Kumar GR, Dhanapal R, Saraswathi T. Sex determination by discriminant function analysis of palatal rugae from a population of coastal Andhra. J Forensic Dent Sci. 2011; 3: 58-62.

[36] Madhan Kumar S, Natarajan S, Maheshwari U, Kumar VA, Veeravalli PT, Banu F. Palatal rugae pattern for gender identification among selected student population in Chennai, India. J Sci Res Rep. 2013; 2: 491–496.