Dental Research Journal

Original Article

Assessment of palatal rugae pattern for sex and ethnicity identification in an iranian population

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ABSTRACT

Background: Palatal rugoscopy is a reliable method in the forensic personal identification and racial group specification. the aim of the present study is to use palatal rugae pattern in sex and ethnicity identification applications.

Materials and Methods: Four hundred individual dental casts from four different ethnic populations of Iran were randomly selected. The pattern of the palatal rugae (shape, length, and number) investigated and its reliability to classify sex and minor ethnicity for each individual cast was evaluated. ($P < 0.05$) considered significant.

Results: The most common rugae shapes were straight, followed by wavy and curved types. The least frequent shapes were converging and circular types. Palatal rugae patterns were unique to each person. However, they could not differentiate males and females and had low abilities to classify the racial subsets.

Conclusion: The palatal rugae pattern was unique to each individual and palatal rugoscopy can be considered as a reliable forensic identification tool where utilizing other methods such as DNA profiling, fingerprint, and dental record comparison is impossible or difficult. In this study, palatal rugoscopy was not a reliable method to classify the sex of an individual and to differentiate between different racial subsets.

Received: January 2017
Accepted: September 2017

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Key Words: Dental records, forensic dentistry, human identification, palate

INTRODUCTION

It is very important to identify the whole or fragmented bodies in forensic medicine.[1] Determining the age, sex, and ethnicity of unidentified human beings is challenging especially in mass disasters.

Ethnicity is a category of people who identify with each other based on similarities such as common ancestral, language, social, cultural, or national experiences.[2] A majority of the population of Iran (approximately 67%–80%) consists of Iranian peoples. The largest groups in this category include Persians (who form the majority of the Iranian population) and Kurds, with smaller communities including Gilakis, Mazandaranis, Lurs, Tats, Talysh, and Baloch.[3]

The most common identification methods that are used include visual identification, fingerprint, and

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How to cite this article: Sheikhi M, Zandi M, Ghazizadeh M. Assessment of palatal rugae pattern for sex and ethnicity identification in an iranian population. Dent Res J 2018;15:50-6.

dental record comparisons, and DNA profiling.[1,4] However, these techniques have some limitations.[1,4,5] Although DNA profiling is an ideal method in forensic identification, with an absolute certainty, it will be expensive and time-consuming to use it in large populations.[1] Visual identification and fingerprint comparison may be limited in situations such as putrefaction, burns, severe trauma, and prolonged immersion in water.[5] On the contrary, teeth are the least destructible part of the body and can remain stable for many years after death, but changes to the teeth may occur by dental treatments such as fillings, crowns, extractions, and trauma and make dental records inconclusive.[6]

Palatoscopy can be used successfully as an adjunct identification tool in circumstances where forensic identification by DNA profiling, fingerprint, and dental record comparison is impossible or difficult.[7] Palatoscopy or palatal rugoscopy is the study of the palatal rugae. It has been shown that palatal rugae are unique for an individual and remain unchanged during individual's lifetime.[7-9] Furthermore, because of their anatomical position inside the oral cavity, palatal rugae have higher probability of remaining intact in trauma, incineration, and decomposition.[1,8,10,11] These unique characteristic make the palatal rugae an ideal and reliable human identification tool.[7]

Several investigations demonstrated an intimate association between palatal rugae pattern and ethnicity.[8,12-14] Although the pattern of palatal rugae has been studied in various populations around the world, this study has not been performed in Iran. Iran is one of the most vulnerable countries of the world for natural disasters, and it has been demonstrated that in these challenging situations the rugae usually remain intact and can be used for identification of unidentifiable people. As a result, considering the high number of Iranians living in other countries, make the palatoscopy to play a significant role in the forensic identification of these expatriates.[15]

The purpose of this study is to assess and to investigate usefulness of palatal rugae patterns in sex and ethnicity identification applications.

MATERIALS AND METHODS

Research Ethics Committee of the Hamedan University of Medical Science approved this research. In this study, 400 individuals' dental casts from four different ethnic population of Iran (natives of Hamedan, Tehran, Kordestan, and Kermanshah) were randomly obtained from dental schools and private dental offices. We just included dental casts with a good quality (free of air bubble or void in anterior palatal area) and with known age, sex, and birthplace in the study. Exclusion criteria were lesion or scar in the anterior palatal region, gross maxillary anomalies, and extraction of the maxillary teeth. We used Thomas and Kotze[16] and Kapali *et al*.[17] categories to classify length and shape of rugae. The outline of the rugae on the casts was delineated using a sharp black graphite pencil [Figure 1]. The palatal rugaes were examined under magnification using a hand magnifying lens. Then, they were classified according to their morphology into following categories [Figure 2].

1. Straight
2. Curved
3. Angle
4. Wavy
5. Circular
6. Diverging: Two rugae that originate from a common point medially and diverge away from the midpalatal line
7. Converging: Two rugae with different origin medially, joining on a common point laterally
8. Branching with divergence: One rugae with two or more branches directed away from midpalatal line
9. Branching with convergence: One rugae with two or more branches directed toward midpalatal line
10. Nonspecific.

To determine the length of the rugae, regardless of their shape, the greatest dimension of the rugae was measured on the casts using a digital caliper (Mitutoyo crop, Kawasaki, Japan) calibrated

Figure 1: Different types of palatal rugae shape delineated in maxillary casts.

to 0.1 mm. The rugae were classified based on their length into following three groups:

- Primary (more than 5 mm)
- Secondary (3–5 mm)
- Fragmentary (<3 mm).

One examiner performed all of the rugae shape and length evaluation. To evaluate the level of intra- and inter-observer agreements, 20% of the casts were randomly selected and assessed by a second examiner. To calibrate the examiners, the second examiner investigated the casts 4 weeks after the first examiner. All data were entered into a checklist and subjected to the statistical analysis.

The statistical tests used in the present study were independent sample *t*-test, one-way analysis of variance, and linear discriminant analysis. To determine the level of intra- and inter-examiner agreements, Cohen's Kappa test was performed. The level of significance was defined as $P < 0.05$. All statistical analyses were done using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) software.

RESULTS

Four hundred individuals Dental casts (186 males and 214 females) aged between 7 and 68 years (mean, 21 years) were included in this study [Table 1].

Kappa statistics revealed a very good intra-examiner ($\kappa = 0.93$) and inter-examiner agreements ($\kappa = 0.91$) in measuring rugae pattern, length, and number of rugae.

Table 1: Age and sex of the samples (*t*-test analysis was used to calculate *P* value)

Province	*n*	Age				*P*
		Minimum	Maximum	Mean	SD	
Hamedan	100	7	63	17.63	12.98	
Male	50	7	63	17.52	12.49	0.395
Female	50	7	52	19.74	13.50	
Tehran	100	14	68	22.56	9.01	
Male	48	15	68	21.83	8.19	0.441
Female	52	14	66	23.23	9.74	
Kordestan	100	8	45	19.56	7.81	
Male	50	9	37	18.28	6.48	0.101
Female	50	8	45	20.84	8.82	
Kermanshah	100	10	60	22.92	11.28	
Male	38	11	60	24.53	14.59	0.267
Female	62	10	45	21.94	8.65	
Total	400	7	68	20.92	10.59	
Male	186	7	68	20.27	10.93	0.252
Female	214	7	66	21.48	10.28	

SD: Standard deviation

The distribution of the shape, length, and total number of rugae in the studied population is illustrated in Table 2 and Figure 3. The most frequent rugae shape were straight (26%), followed by wavy (21%), and curved (16%) types. In males, the most common rugae shape were straight (27%), followed by wavy (21%), and branching with divergence (16%) types. In females, the predominant rugae shape were straight (26%), followed by wavy (21%), and curved (17%) types. In both males and females, the most common rugae lengths were primary, followed by secondary and fragmentary types. According to the sample *t*-test analysis, there was no significant statistically difference between males and females regarding to the shape, length, and total number of rugae ($P < 0.05$).

By categorizing the patients into six age groups (7–15 years, 15–25 years, 25–35 years, 35–45 years,

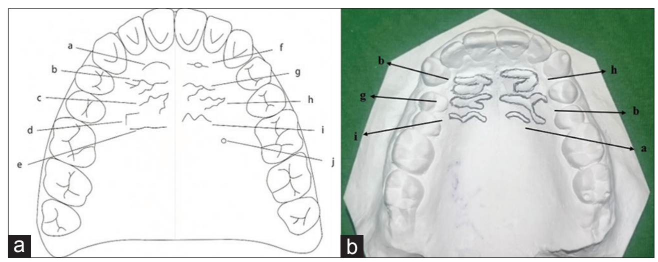

Figure 2: (a) All types of palatal rugae pattern, (a) curved, (b) branching with divergence, (c) diverging, (d) angle, (e) straight, (f) circular, (g) branching with convergence, (h) converging, (i) wavy, (j) nonspecific. (b) Palatal rugae pattern in a cast model.

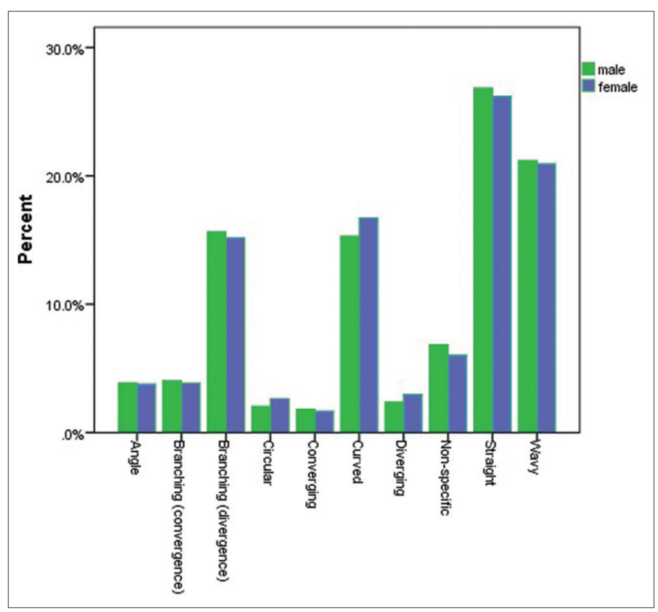

Figure 3: Frequency distribution of the different shape of rugae among males and females.

Table 2: Distribution of shape, length, and number of the rugae in studied population (*t*-test analysis was used to calculate *P* value)

Rugae pattern	Total (*n*=400)			Male (*n*=186)			Female (*n*=214)			*P*
	Range	Mean (SD)	Sum (%)	Range	Mean (SD)	Sum (%)	Range	Mean (SD)	Sum (%)	
Figure										
Straight	0-8	2.58 (1.74)	1033 (26)	0-8	2.61 (1.82)	486 (27)	0.8	2.56 (1.68)	547 (26)	0.746
Curved	0-6	1.57 (1.26)	626 (16)	0-6	1.49 (1.25)	277 (15)	0.6	1.63 (1.27)	349 (17)	0.264
Angle	0-3	0.37 (0.63)	149 (4)	0-3	0.38 (0.62)	70 (4)	0.3	0.37 (0.63)	79 (4)	0.909
Wavy	0-8	2.05 (1.43)	821 (21)	0-7	2.06 (1.38)	384 (21)	0.8	2.04 (1.47)	437 (21)	0.876
Circular	0-2	0.23 (0.48)	92 (2)	0-2	0.20 (0.45)	37 (2)	0.2	0.26 (0.51)	55 (3)	0.23
Converging	0-3	0.17 (0.46)	68 (2)	0-2	0.18 (0.42)	33 (2)	0.3	0.16 (0.49)	35 (2)	0.764
Diverging	0-3	0.26 (0.54)	105 (3)	0-2	0.23 (0.49)	43 (2)	0.3	0.29 (0.58)	62 (3)	0.262
Branching										
Convergence	0-3	0.38 (0.61)	153 (4)	0-2	0.39 (0.58)	73 (4)	0.3	0.37 (0.63)	80 (4)	0.759
Divergence	0-5	1.50 (1.06)	600 (15)	0-5	1.52 (1.05)	283 (16)	0.4	1.48 (1.07)	317 (15)	0.706
Nonspecifc	0-6	0.63 (0.98)	250 (6)	0-6	0.67 (1.05)	124 (6)	0.5	0.59 (0.91)	126 (6)	0.428
Length										
Primary	4-13	7.84 (1.89)	3135 (81)	4-12	7.82 (1.63)	1455 (80)	4.13	7.85 (1.75)	1680 (81)	0.870
Secondary	0-8	1.38 (1.41)	552 (14)	0-8	1.38 (1.46)	257 (14)	0.6	1.38 (1.36)	295 (14)	0.982
Fragmentary	0-4	0.51 (0.86)	206 (5)	0-4	053 (0.84)	98 (5)	0.4	0.50 (0.89)	108 (5)	0.797
Total of rugae	5-20	9.73 (2.57)	3892 (100)	5-20	9.73 (2.68)	1810 (100)	5.16	9.73 (2.48)	2082 (100)	0.993

SD: Standard deviation

45–55 years, and 55–68 years), no significant statistically difference were found between these groups regarding to the rugae shape, length, and number of rugae (table is not presented).

Evaluation of the rugae pattern in the four population groups by one-way analysis of variance, revealed that there was significant statistically difference regarding to the total rugae number, rugae length, and four rugae shapes including straight, wavy, circular, and nonspecific shapes ($P < 0.05$) [Table 3].

In the present study and according to the rugae pattern, the stepwise discriminant function analysis was performed to classify sex and population types. For the sex classification, no variables could qualify the analysis. When all the rugae shape and length variables were entered in the analysis, they could not classify the sex of an individual.

For population type classification, variables including wavy, nonspecific, and primary rugae patterns entered the analysis. However, they had a low ability to differentiate between the population groups. The classification results of the discriminant analysis for population group and sex are presented in Tables 4 and 5.

The present study also confirmed the uniqueness of the rugae morphology for each person. Indeed, no two individual's rugae patterns were found to be alike in their morphology.

DISCUSSION

Palatal rugae are transverse, irregular, and asymmetric ridges of the mucous membrane that are situated in the anterior part of the palate behind the incisive papillae.[18] During the 3rd month of intrauterine life, palatal rugae appear as localized epithelial thickening, next to the incisive papillae. They are completely formed by the 12th to 14th of the prenatal life.[13] Thereafter, they experience changes in their size because of growth, but their shape remains stable.[18,19] It is claimed that the hydrophilic nature of the glycosaminoglycans, which are abundantly present in the rugae connective tissue, contributes to the maintenance of the rugae throughout the life.[8]

A characteristic of palatal rugae that make it an ideal tool for forensic personal identification is its uniqueness for each person. There is a consensus in the literature that palatal rugae pattern, analogous to fingerprint, is unique to an individual.[7-9]

Other advantages of palatal rugae are their internal position in the oral cavity and their protection by teeth, cheeks, lips, and tongue. Hence, the probability of their morphology variation in trauma, chemical attack, and fire is very low.[13] Furthermore, it was demonstrated that the palatal rugae remain unchanged after various treatments such as tooth movement, palatal expansion, and tooth extraction.[1,20]

Table 3: Distribution of the rugae pattern in the four population groups (*P*-value was calculated by one-way analysis of variance)

Rugae pattern	Hamedan (*n*=100)			Tehran (*n*=100)			Kordestan (*n*=100)			Kermanshah (*n*=100)			*P*
	Mean	SD	Sum (%)	Mean	SD	Sum (%)	Mean	SD	Sum (%)	Mean	SD	Sum (%)	
Figure													
Straight	2.52	1.96	252 (24)	2.00	1.41	200 (24)	2.99	1.72	299 (30)	2.82	1.71	282 (27)	<0.001
Curved	1.72	1.41	172 (16)	1.32	1.22	1.32 (16)	1.55	1.16	155 (16)	1.67	1.23	167 (16)	0.11
Angle	0.32	0.57	32 (3)	0.32	0.57	32 (4)	0.39	0.63	39 (4)	0.46	0.73	46 (4)	0.33
Wavy	2.52	1.84	252 (24)	1.82	1.26	182 (22)	1.95	1.12	195 (20)	1.92	1.31	192 (18)	0.002
Circular	0.15	0.43	15 (1)	0.18	0.43	18 (2)	0.26	0.52	26 (3)	0.33	0.51	33 (3)	0.036
Converging	0.16	0.46	16 (2)	0.11	0.40	11 (1)	0.22	0.50	22 (2)	0.19	0.46	19 (2)	0.375
Diverging	0.20	0.47	20 (2)	0.28	0.60	28 (3)	0.25	0.56	25 (3)	0.32	0.53	32 (3)	0.458
Branching													
Convergence	0.44	0.67	44 (4)	0.30	0.50	30 (4)	0.38	0.57	38 (4)	0.41	0.67	41 (4)	0.399
Divergence	1.49	1.16	149 (14)	1.35	1.06	135 (16)	1.54	0.99	154 (16)	1.62	1.02	162 (16)	0.33
Nonspecifc	0.93	1.15	93 (9)	0.50	1.01	50 (6)	0.37	0.66	37 (4)	0.70	0.95	70 (7)	<0.001
Length													
Primary	7.97	1.75	797 (76)	6.90	1.31	690 (84)	8.09	1.75	809 (82)	8.39	1.56	839 (80)	<0.001
Secondary	1.67	1.72	167 (16)	0.97	1.18	97 (12)	1.38	1.20	138 (14)	1.50	1.37	150 (14)	0.003
Fragmentary	0.82	0.99	82 (8)	0.31	0.78	31 (4)	0.38	0.74	38 (4)	0.55	0.84	55 (5)	<0.001
Total of rugae	10.46	2.69	1046 (100)	8.18	2.26	818 (100)	9.84	2.28	984 (100)	10.44	2.37	1044 (100)	<0.001

SD: Standard deviation

Table 4: Classification results of discriminant analysis to differentiate sex according to rugae pattern

Sex	Predicted group membership				Total	
	Male		Female			
	Number	Percentage	Number	Percentage	Number	Percentage
Male	106	57.0	80	43.0	186	100.0
Female	108	55.5	106	44.5	204	100.0

Table 5: Classification results of discriminant analysis to differentiate population group according to rugae pattern

Population type	Predicted group membership								Total	
	Tehran		Hamedan		Kermanshah		Kordestan			
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Tehran	61	61.0	16	16.0	7	7.0	16	16.0	100	100.0
Hamedan	25	25.0	41	41.0	16	16.0	18	18.0	100	100.0
Kermanshah	25	25.0	23	23.0	31	31.0	21	21.0	100	100.0
Kordestan	27	27.0	18	18.0	19	19.0	36	36.0	100	100.0

Palatal rugae patterns are reported to be specific to racial groups.[12-14,17,21-23] The present study showed that the most common rugae shapes in Iranian were straight, followed by wavy, and curved type. The least frequent shapes were converging and circular types.

Santos and Caldas reported that the straight type was the most common rugae shape in Portuguese population.[24] However, investigations conducted on various Indian ethnic populations showed that the wavy and curved types were the most predominant rugae shapes.[4,8,9,14,15,23,25]

Abdellatif *et al*. in a study compared the Palatal rugae pattern of samples from Egyptian with Saudi children. They found that curved and wavy were the most prevalent rugae shape in both groups.[23]

In an investigation by Kallianpur *et al*. on Indian and Nepalese populations, it was found that the predominant shape of palatal rugae in both populations was wavy type, which was in accordance with the results observed in Caucasian and Australian races.[17,26]

The second common rugae shape in Indians, Australian aborigines, and Caucasians was curved type while in the Nepalese, it was straight type. Straight type has been reported to be uncommon in aborigines and Caucasians.[17,26]

In the present study, the most common rugae length was primary type which was matched with the findings of the studies by Surekha *et al*., Paliwal *et al*., Gondivkar *et al*., Bharath *et al*., and Kapali *et al*.[9,17,18,21,25]

The difference in rugae pattern observed in different racial group has been attributed to the interracial genetic differences.[27] Although rugae morphology may be influenced by environmental factors, it is mostly genetically controlled. It is claimed that during embryogenesis and postnatal growth, several genes determine the orientation of collagen fibers within rugae connective tissue and hence govern rugae pattern in various racial groups.[11] The finding of twin studies further confirm the role of genetic influence in determining rugae pattern.[13,27,28]

Some investigators reported that not only the palatal rugae has distinct presentation pattern in different racial groups but also within the subsets of a single race.[9,26,29]

In studies by Paliwal *et al*. and Surekha *et al*., a significant statistically association (although subtle) between the rugae shape in different Indian populations was observed.[9,25] In a study by Shanmugam *et al*., palatal rugoscopy was reported to be accurate enough to differentiate Southern Indian and Northern Indian populations.[14] Present investigation showed a significant statistically difference in rugae shape, number, and length between four different Iranian populations. However, discriminant function analysis demonstrated that palatoscopy had a low ability to differentiate between the population groups, Accordingly, Thomas and Kotze assessed rugae pattern in six different South African populations and stated that the palatal rugae cannot determine the race of an individual.[30] Therefore, the role of palatal rugae in the differentiation of racial subgroups remains controversial.

The reliability of palatal rugae pattern in sex differentiation has been evaluated in several investigations.[1,4,12,21-23,29-32]

Chatterjee and Khanna reported that the rugae with separate origin showed a strong female predilection while rugae with the common origin, fragmentary, and lateral branching patterns were more common in males.[12] Accordingly, in a study by Bharath *et al*., it was found that a significant difference in the total number and unification pattern of rugae existed between males and females.[21] An investigation on a Japanese population showed that females had fewer rugae than males.[31] Shetty *et al*. reported that Indian males had more primary rugae on the left side than females and vice versa for the Tibetan population.[29] In a study by Saraf *et al*., it was revealed that the converging types of rugae were more frequent in males, and the circular types were more common in females. In their study, the use of logistic regression analysis enabled them to have highly accurate sex prediction.[4]

In contrast, the present study revealed that the shape, length, and total number of rugae were not significantly different between males and females. Discriminant function analysis was not able to classify the sex of the individuals according to the rugae pattern. Sharma *et al.*, Nayak *et al.*, and several other authors also demonstrated that palatal rugoscopy is not reliable in identifying the sex of an individual, which was in agreement with the findings of the present study.[13,22,23,32]

One of the specific features that make our study preferable compare to others is the vast number of our population samples. Our study was carried on 400 rugae samples. This fact makes our results more reliable and accurate.

The controversial results of the previous studies, regarding to the reliability of palatal rugoscopy in sex and racial subset differentiation, may be partly because of factors such as sample size and methodological differences between previous investigations racial and geographical variations among populations being studied. Also, the lack of a standard universally accepted system for classification of palatal rugae pattern may cause different results. Therefore, further race specific researches using a large sample size and standard classification system is recommended.

CONCLUSION

The present study demonstrated that the most common rugae shapes in the Iranian population were straight, followed by wavy and curved types. It was observed that the palatal rugae pattern was unique for each individual. However, palatal rugoscopy was not a reliable method to classify the sex of an individual and to differentiate between different racial subsets.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial, or nonfinancial in this article.

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