Morphological analysis of palatal rugae patterns in a population of Maharashtrian ancestry: a cross-sectional study

Vibhuti Shreesh Mhatre[1],
Jigna Pathak [2],
Shilpa Patel [1],
Leela S. Poonja [1],
Niharika Swain [1],
Kamlesh Dekate [1],
Amit Bhandarwar [1]

[1] Department of Oral & Maxillofacial Pathology, MGM Dental College & Hospital, Navi Mumbai - India
[2] Department of Oral & Maxillofacial Pathology, MGM Dental College & Hospital and MGMIHS, Navi Mumbai - India

Corresponding author:
drjignapathak@gmail.com

The authors declare that they have no conflict of interest.

KEYWORDS

Palatal rugae,
Ancestry,
Identification tool.

J Forensic Odontostomatol
2020. Sep;(38): 2-12:21
ISSN :2219-6749

ABSTRACT

Aim: To analyze the morphological parameters of palatal rugae in a population of Maharashtrian ancestry.

Material and methods: This study was conducted on 1000 subjects of Maharashtrian ancestry with at least 3 generations on the mother's and father's side. Their palatal impressions were obtained with alginate and the casts were analyzed for length, shape and direction of palatal rugae.

Results: Our results showed that the most predominant rugae were primary followed by secondary and fragmentary with significant differences between them. The most prevalent rugae shapes found were straight followed by wavy followed by curved with significant differences between them. According to direction, forward rugae were significantly higher than perpendicular rugae and backward rugae.

Conclusion: The rugae are considered to have population specific configurations. This baseline data of patterns of palatal rugae in a sample of Maharashtrian ancestry may serve `as an accessory tool' for population identification in Forensic Dentistry.

INTRODUCTION

Palatoscopy or palatal rugoscopy is the name given to the study of palatal rugae in order to establish a person's identity. Palatal rugae (rugae palatinae or plicae palatinae transversae) are defined, according to the Glossary of Prosthodontics Terms, as anatomical folds or wrinkles; the irregular ridges of folds of fibrous connective tissue located on the anterior third of the palate behind the incisive papilla. Rugae are secured at an internal position in the oral cavity and are well protected by the lips, cheeks, buccal pad of fat, tongue, teeth and bone and hence are protected from trauma and high temperatures. Their uniqueness, stability and resistance to damage facilitate their use in forensic investigations.

When it is difficult to identify the individual by conventional methods such as fingerprints or DNA analysis, particularly in cases of fragmented bodies in mass disasters, palatal rugoscopy can serve as an alternative method in human identification. There seems to be a remarkable association between rugae forms and ethnicity of a person. Previous literature states that palatal rugae patterns may be specific to racial groups facilitating population identification.[1] The few studies which are done to find this association, show that specific patterns are predominant in specified populations.[1] Hence this study was undertaken to analyze the morphological parameters of palatal rugae and determine the predominant palatal rugae pattern in a population of Maharashtrian ancestry visiting our dental institution.

MATERIAL AND METHODS

This cross-sectional study was conducted on 1000 subjects of Maharashtrian ancestry with at least 3 generations on the mother's and father's side on the basis of convenient sampling. Our sample was equally divided between males and females. Informed consent was obtained from all the participants.

Inclusion Criteria:

- Maharashtrians with at least 3 generations on the mother's and father's side[5] visiting our dental institution.
- Individuals between 18-60 years of age.
- Healthy individuals without any pathology in the palatal region.

Exclusion Criteria:

- Individuals with any palatal pathology.
- Individuals not willing to participate in the study
- Individuals who have undergone / undergoing orthodontic treatment.
- Individuals with extreme finger sucking habit during childhood.
- Subjects with edentulous maxillary arch.
- Individuals wearing maxillary denture.

The palatal impressions were obtained using alginate impression material and the casts were poured with type III dental stone. In the present study, dental casts were used due to their simplicity, easy production, low cost and reliability. The rugae were highlighted using sharp graphite pencils and analysis of rugae patterns in terms of number, length, shape and direction was done.

The most accepted classification systems are by Lysell in 1955[3] and Thomas & Kotze in 1983.[4-6] Lysell classified palatal rugae according to length as primary rugae - rugae which are more than 5 mm in length, secondary rugae - rugae which are 3-5 mm in length and tertiary or fragmentary rugae - rugae which are 2-3 mm in length. (Fig.1) The length of an individual ruga is measured from its starting point near the mid-palatine raphe to its end point transversely. Rugae with lengths of less than 2 mm are not considered. In the current study, the method of rugae classification used was that followed by Ahmed (2015)[5], as we found it to be very detailed. The shapes of the rugae were categorized into five major types: straight, curved (Fig.2), wavy (Fig.3), circular (Fig.4) and angular (Fig.5). The united rugae were categorized into unification (Figs.6 and 7), branching (Fig.3), and crosslink (Fig.8). The unification was further subclassified into diverging (Fig.6) and converging rugae (Fig.7). Any rugae shape that did not fit this classification was considered as nonspecific (Fig.9). The direction of each primary ruga was classified according to the angle between the line joining its origin and termination with a line perpendicular to the median palatal raphae. Forward-directed rugae corresponded with positive angles. Backward-directed rugae corresponded with negative angles, and perpendicular rugae corresponded with no angle (Fig.10).[5]

Figure 1. a: Primary rugae, b: Secondary rugae, c: Fragmentary rugae

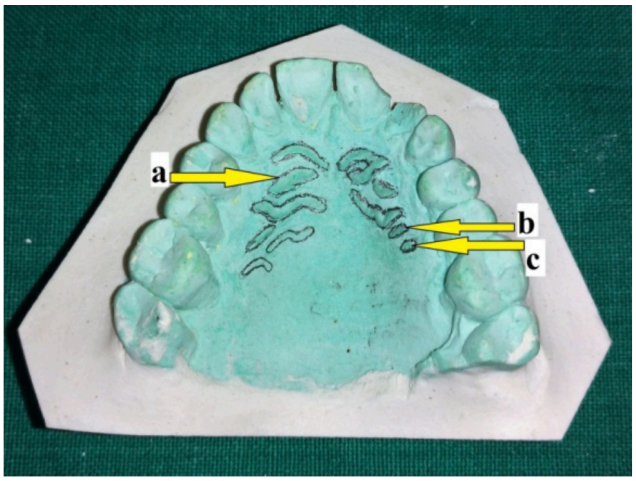


Figure 2. d: Curved rugae, e: Straight rugae

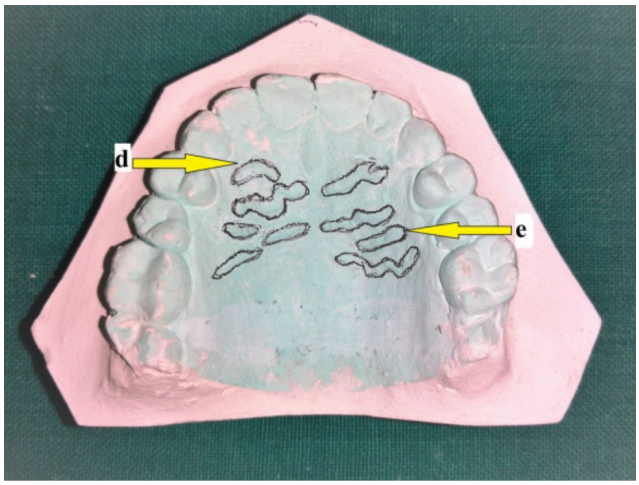


Figure 3. f: Wavy rugae, g: Branched rugae

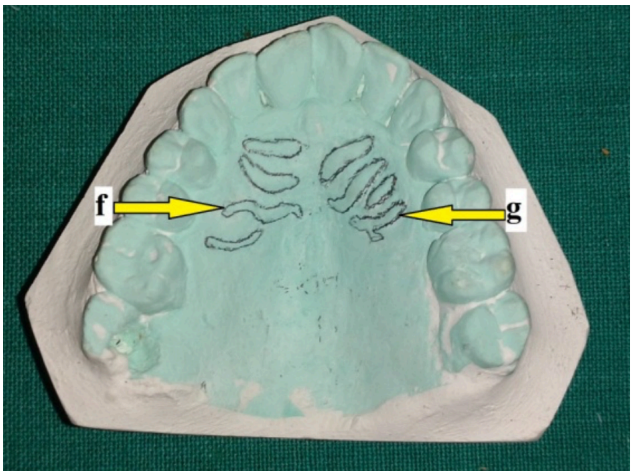


Figure 4. h: Circular rugae

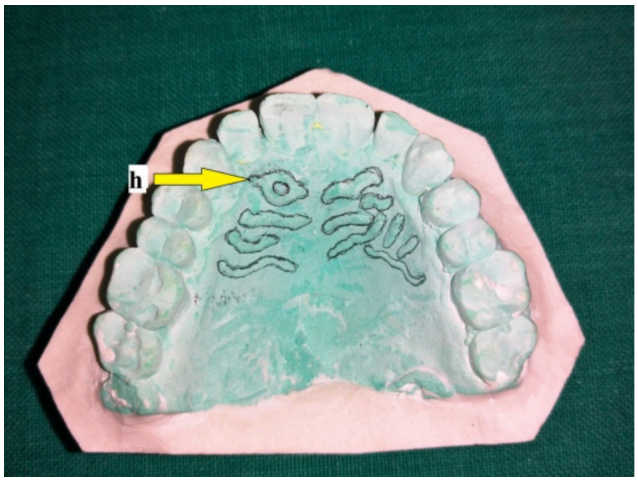


Figure 5. i: Angular rugae

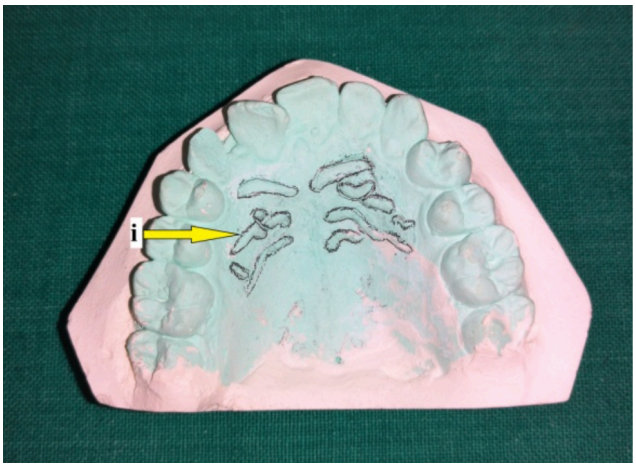


Figure 6. j: Diverging rugae

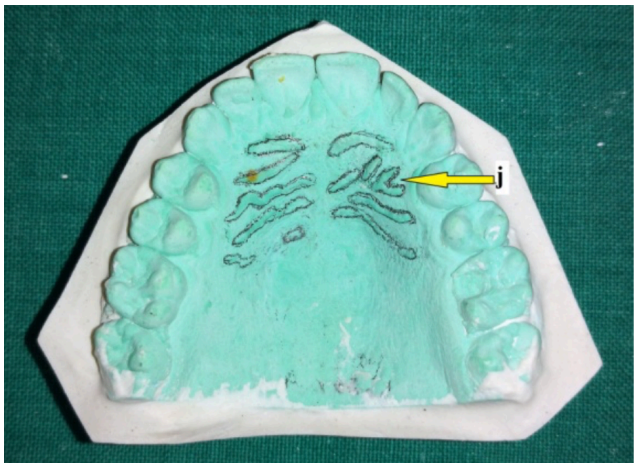


Figure 7. k: Converging rugae

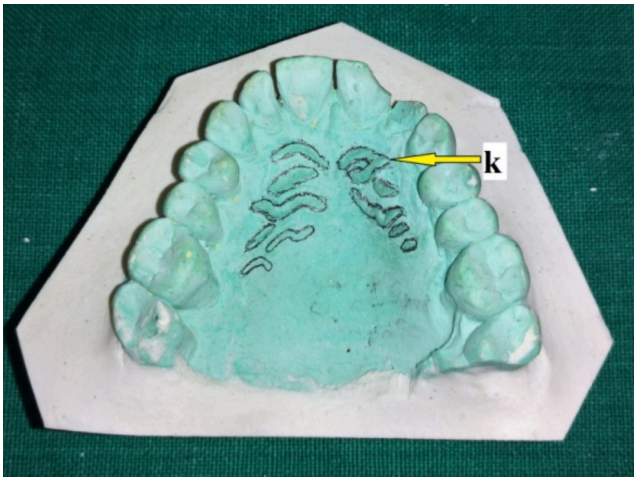


Figure 8. l: Crosslink rugae

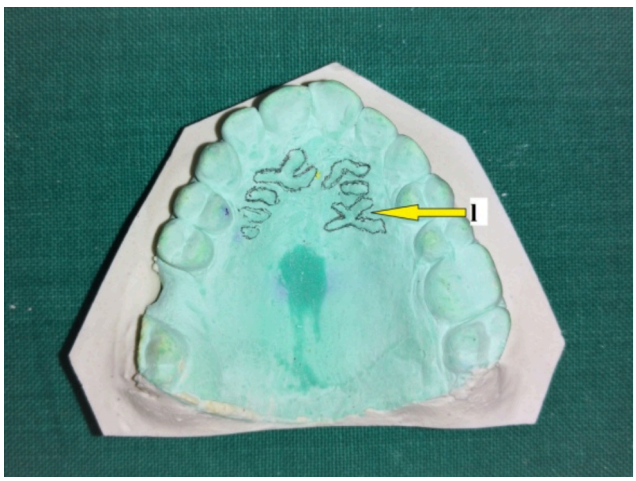


Figure 9. m: Nonspecific rugae

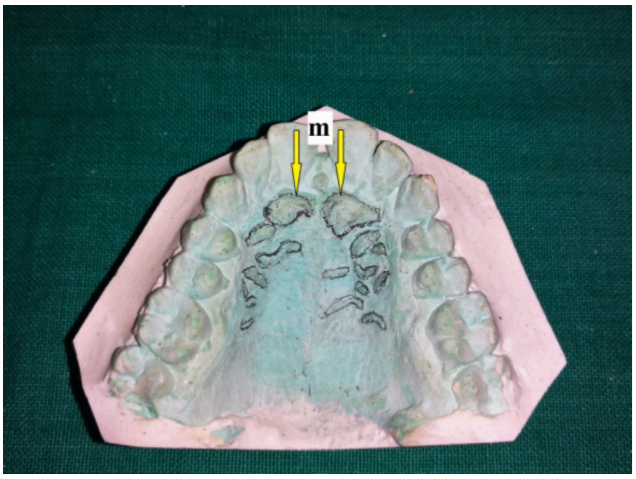
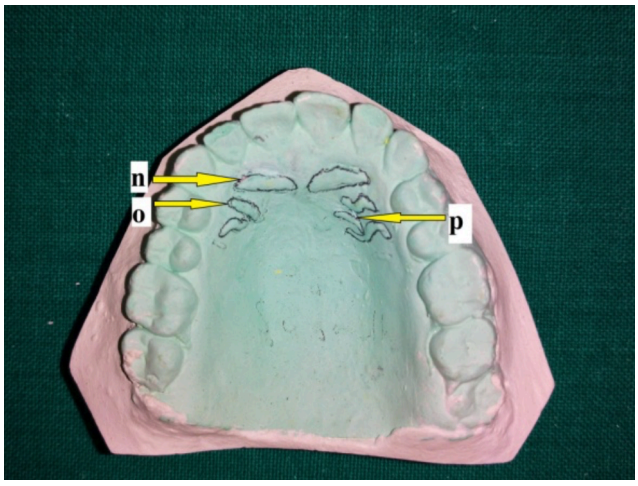


Figure 10. n: Perpendicular rugae, o: Forward rugae, p: Backward rugae



RESULTS

The casts were analyzed by one independent observer and the numbers of rugae were counted in all the casts. Results on continuous measurements were presented as Mean ± SD. Level of significance was fixed at p=0.05 and any value less than or equal to 0.05 was considered to be statistically significant. The Statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data.

The results of the present study showed that the mean of the total number of rugae was 9.49 in males (n=500) and 9.08 in females (n=500). Statistical comparison of the total number of rugae in terms of the mean among males and females performed using unpaired t-test revealed significant difference (p<0.001). (Table 1) el *(-0.92 years)* and 1 tooth model *(-0.86 years)*.

Overall comparison of the mean number of palatal rugae patterns according to length i.e. primary, secondary and fragmentary also showed statistically significant differences (p<0.001). (Table 2) Gender wise comparison of the mean number of rugae according to length showed that the mean number of primary rugae was the highest followed by secondary and fragmentary rugae in both males and females. However, the mean number of only primary rugae was significantly higher in males than that in females. (Table 2A)

Table 1. Comparison of total no of rugae in terms of {Mean (SD)} among males and females using unpaired t-test

Gender	N	Mean	Std. Deviation	t value	P value
Male	500	9.49	1.763	**3.715**	**<0.001****
Female	500	9.08	1.710		

Table 2. Comparison of the palatal rugae patterns {length – Primary, Secondary and Fragmentary} in terms of {Mean (SD)} using ANOVA test

Group	N	Mean	Std. Deviation	F value	P value
Primary	1000	7.78	1.493	**12552.7540**	**<0.001****
Secondary	1000	1.32	1.226		
Fragmentary	1000	0.19	0.525		

(Tukey's post hoc analysis)

	Primary	*Secondary*	*Fragmentary*
Primary	-	<0.001**	<0.001**
Secondary	<0.001**	-	<0.001**
Fragmentary	<0.001**	<0.001**	-

Table 2A. Comparison of the palatal rugae patterns {length – Primary and Secondary} in terms of {Mean (SD)} among males and females using unpaired t-test and comparison of the palatal rugae patterns {length - fragmentary} among males and females using Mann Whitney U-test

	Gender	**N**	**Mean**	**Std. Deviation**	**t value**	**P value**
Primary	Male	500	8.04	1.460	**5.657**	**<0.001****
	Female	500	7.51	1.480		
Secondary	Male	500	1.28	1.242	1.135	0.257
	Female	500	1.36	1.209		
	(p < 0.05 - Significant*, p < 0.001 - Highly significant**)					
	Gender	**N**	**Mean**	**Std. Deviation**	**Z value**	**P value**
Fragmentary	Male	500	0.18	0.485	0.499	0.618
	Female	500	0.21	0.563		

Evaluation of the mean number of rugae according to shape showed that straight rugae (mean = 3.55) was the highest followed by wavy rugae (mean = 2.85), followed by curved rugae (mean = 1.85). For statistical comparisons, only straight, wavy and curved rugae were considered as they were higher in number and the majority of studies have also considered these three shapes. Overall comparison of the mean number of palatal rugae patterns according to shape also showed statistically significant differences ($p<0.001$). (Table 3) Gender wise statistical comparison of the mean number of rugae patterns according to shape (straight, wavy, curved) was done using unpaired t-test, which revealed that the mean number of wavy rugae was significantly higher in males than that in females. (Table 3A)

Table 3. Comparison of the palatal rugae patterns {Curved, Wavy, Straight} in terms of {Mean (SD)} using ANOVA test

Group	**N**	**Mean**	**Std. Deviation**	**F value**	**P value**
Curved	1000	1.85	1.360	276.4974	<0.001**
Wavy	1000	2.85	1.595		
Straight	1000	3.55	1.878		

(Tukey's post hoc analysis)

	Primary	*Secondary*	*Fragmentary*
Primary	-	<0.001**	<0.001**
Secondary	<0.001**	-	<0.001**
Fragmentary	<0.001**	<0.001**	-

Table 3A. Comparison of the palatal rugae patterns {shape - straight, wavy, curved} in terms of {Mean (SD)} among males and females using unpaired t-test

	Gender	**N**	**Mean**	**Std. Deviation**	**t value**	**p value**
Straight	Male	500	3.51	1.902	0.673	0.501
	Female	500	3.59	1.855		
Wavy	Male	500	3.08	1.636	4.443	<0.001**
	Female	500	2.63	1.522		
Curved	Male	500	1.80	1.315	1.139	0.255
	Female	500	1.90	1.404		

Evaluation of the mean number of rugae according to direction showed that forward rugae (mean = 3.83) was the highest followed by perpendicular rugae (mean = 2.78), followed by backward rugae (mean = 2.67). The mean number of forward rugae was significantly higher than the mean number of backward and perpendicular rugae. (Table 4)

Gender wise comparison of the mean number of rugae patterns according to direction (forward, backward, perpendicular) was done using unpaired t-test, which revealed that the mean number of perpendicular rugae was significantly higher amongst males (mean = 2.92) than females (mean = 2.64). (Table 4A)

Table 4. Comparison of the palatal rugae patterns {Forward, Backward and Perpendicular} in terms of {Mean (SD)} using ANOVA test

Group	**N**	**Mean**	**Std. Deviation**	**F value**	**P value**
Forward	1000	3.83	2.259	106.2640	<0.001**
Backward	1000	2.67	1.798		
Perpendicular	1000	2.78	1.800		

(Tukey's post hoc analysis)

	Primary	*Secondary*	*Fragmentary*
Primary	-	<0.001**	<0.001**
Secondary	<0.001**	-	0.4226
Fragmentary	<0.001**	0.4226	-

Table 4A. Comparison of the palatal rugae patterns {direction - forward, backward, perpendicular} in terms of {Mean (SD)} among males and females using unpaired t-test

	Gender	N	Mean	Std. Deviation	t value	p value
Forward	Male	500	3.89	2.294	0.756	0.450
	Female	500	3.78	2.223		
Backward	Male	500	2.68	1.864	0.158	0.874
	Female	500	2.66	1.730		
Perpendicular	Male	500	2.92	1.890	2.483	0.013*
	Female	500	2.64	1.696		

($p < 0.05$ - Significant*, $p < 0.001$ - Highly significant**)

DISCUSSION

The variations in rugae patterns observed may be associated with the interracial genetic differences. Although rugae pattern morphology may be impacted by environmental factors, it is also genetically controlled. It was hypothesized that various genes govern the orientation of collagen fibres within rugae connective tissue during embryogenesis and post-natal growth, which in turn is responsible for differences in rugae patterns in different racial groups. The research performed on twins further ascertains the fact of genetic influence playing a role in determining rugae pattern.[3,7,] Since palatal rugae are specific to racial groups, they may be used for population identification. We designed this study to explore the unique patterns of palatal rugae in a homogenous population of Maharashtrians with 3 generations on the mother's and father's side.

The results of the present study showed that the mean number of rugae was 9.49 in males (n=500) and 9.08 in females (n=500) and the difference between them was statistically significant. Our results in terms of the mean number of rugae were comparable to the studies done on Gujarati and Uttar Pradesh populations. The number of rugae were less than compared to Central Indian population, Coastal Andhra population and Sudanese population[5], whereas it was more than in Jordanian population, Lucknow Population, the Australian aborigines[1], Meerut Population and in the Indian population. Our results in terms of the number of rugae amongst males and females were evaluated and the difference was statistically significant as in Central Indian population[12] and also in a study by Gautam N.[8-21]

The mean number of primary rugae was highest followed by secondary followed by fragmentary rugae in the total study population (n=1000) and this difference was statistically significant ($p<0.001$). These results were comparable to Jordanian population[14], Egyptian population, Coastal Andhra Population[13] and in Yeroba and Igbo populations of Nigeria when both populations were combined. On gender wise statistical evaluation, the mean number of only primary rugae was found to be significantly higher in males. Primary rugae in males were significantly higher than females in Sudanese population[5], West Godavari population and in a study by Balgi as well as by Gautam[18]. Our results were contradictory to the study performed on Nalgonda paediatric population which showed significantly higher primary rugae in females than males and significantly higher secondary rugae in males than females. The more primary rugae in males than females can be due to variations in palatal width, as males have larger palates than females, allowing them to have lengthier rugae.

In our study, evaluation of the mean number of rugae according to shape showed that straight rugae was the highest followed by wavy rugae followed by curved rugae and this difference was statistically significant. The least common was crosslink rugae in the total sample as well as in both males and females. For statistical comparisons, only straight, wavy and curved rugae were considered as they were higher in number and the majority of studies have also considered these three shapes. Our results were in accordance with Egyptian[19] population, Tharu population, Gujrati population[10], Andhra

population, Malyalees. Crosslink rugae which were the least common type which was similar to the results in Sudanese population[5] in which the sample selection criteria were similar to the one chosen in our study (3 generations on the mother's and father's side).[22-26] Gender wise statistical comparison showed that the mean number of wavy rugae was significantly higher in males than that in female as in a study on Lucknow population[15]. Study on Telangana population and in a study by Gautam[18], found significantly higher wavy rugae pattern in females than males. Our results were contradictory to study on Malayalees[27] and by Balgi[22] which showed that males had significantly higher straight rugae than females.

Evaluation of the mean number of rugae according to direction showed that forward rugae was the highest followed by perpendicular rugae followed by backward rugae. The mean number of forward rugae was significantly higher than the mean number of backward and perpendicular rugae. Statistically significant differences in all rugae patterns according to directions were also found in Egyptian[19], Jordanian[14] and Sudanese[5] populations and contrary to the results seen in Gujarati[10] population where perpendicular rugae was highest. Gender wise evaluation of the mean number of rugae in males (n=500) according to direction showed that forward rugae was the highest followed by perpendicular and backward and in females (n=500), forward rugae was the highest followed by backward rugae and perpendicular rugae. On statistical evaluation, the mean number of perpendicular rugae was significantly higher amongst males than females. To the best of our knowledge, no other study showed statistically significant difference in the mean number of perpendicular rugae among males and females.

Various studies are carried out in the literature where straight, wavy and curved are predominantly found. Amongst Indian population studies, wavy is the most common and circular is the least common (<5%). However, in our study, circular shape was even less, only 0.6%. (Table 5) In our study, straight is more common and crosslink is the least common. (Table 5) In Indians, straight is the most predominant only in Gujarati[10] and Andhra populations[26] where sample size considered was only 100 subjects. Thus, the reliability of these studies is questionable. Sample size of 1000 subjects was seen in only one other study on Lucknow population[15]. Genetic basis (3 generations on maternal and paternal side) to obtain a homogenous sample was considered in only two other studies conducted on Nigerian and Sudanese populations[5] and on no studies on Indian population. Discrepancy in the results of various studies could be attributed to sample selection, sample size and various classification methods used.

Table 5. Rugae shapes and their percentage

Rugae shape	Overall percentage (%)
Curved	19.48
Wavy	30.73
Straight	38.22
Circular	0.6
Branched	2.56
Crosslink	0.6

Since a mixture of various patterns is obtained in our study and similar patterns maybe seen in different population groups, this study does not preclude identification based on palatal rugae patterns of an individual unless the pattern has been stored as a previous ante-mortem record in the form of a dental cast or its image. Rugoscopy is highly individualistic and can only be used as a supplementary tool for personal identification and sex determination. Importantly, palatal rugoscopy is not legitimate as evidence in a court of law currently.[11] The reliability and validity of research on tools for population identification , using racial / ancestral background, can be authenticated only if concrete criteria and guidelines can be formulated for homogenous sample selection which should be followed by all researchers for comparable results. Only then, the credibility of using a combination of all accessory tools in population identification of a specific racial group could be emphasized as a cheaper and reliable modality as compared to genetic analysis.

There were certain limitations of our study scanning digital technology would provide three-dimensional records which could be obtained faster and would be more precise

Multiple combinations of geometric variables maybe of more value than individual parameters

Molecular forensics, when available, defy the usage of morphological methods such as palatal rugae, which obviously have not occurred in routine forensic and medico-legal assessment.[1]

CONCLUSIONS

The palatal rugae patterns were analyzed in a population of Maharashtrian ancestry, which showed that the most predominant rugae were primary, and the most prevalent rugae shapes found were straight followed by wavy followed by curved. Also, forward rugae were the highest followed by perpendicular rugae followed by backward rugae. Since rugae are said to be genetically controlled, a homogenous sample selection based on ancestry should be emphasized. A larger sample size will give a more predictable database. There is a need for a standardized classification system to have comparable data. The least common shape may serve as a better population indicator. Preliminary studies should be carried out on a large homogenous sample to provide cut-off values for the total number of rugae in males and females in a specific population selected on the basis of ancestry. This baseline data may thus be valuable for future research on population based studies.

REFERENCES

1. Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian Aborigines and Caucasians: Australian Dental Journal 1997; 42:(2):129-3.
2. Filho IE, Sales–Peres SH, Sales–Peres A, Carvalho SP. Palatal rugae patterns as bioindicator of identification in forensic dentistry. RFO 2009;14:227–33.
3. Lysell L. Plicae palatinae transversae and papilla incisiva in man; a morphologic and genetic study. Acta Odontol Scand 1955;13 Suppl 18:5-137.
4. Bhullar A, Kaur RP, Kamat MS. Paltal rugae: an aid in clinical dentistry, J Forensic Res 2011, 2:124.
5. Ahmed AA, Hamid A, Morphological study of palatal rugae in a Sudanese population, Int J Dent. 2015; 2015:650648
6. Thomas CJ, Kotze TJ, "The palatal ruga pattern: a new classification.," J Dent Assoc S Afr. 1983;38(3),153–7.
7. Thomas CJ, Kotze TJ. The palatal ruga pattern in six southern African human populations, part I: A description of the populations and a method for its investigation. J Dent Assoc S Afr 1983;38:547–53.
8. Venegas VH, Valenzuda JS. Palatal rugae: Systematic analysis of its shape and dimensions for use in human identification. Int J Morphol 2009;27:819–25.
9. Nayak P, Acharya AB, Padmini AT, Kaveri H. Differences in the palatal rugae shape in two populations of India. Arch Oral Biol 2007;52:977–82.
10. Pillai J, Banker A, Bhattacharya A, Gandhi R, Patel N, Parikh S. Quantitative and qualitative analysis of palatal rugae patterns in Gujarati population: A retrospective, cross-sectional study. J Forensic Dent Sci 2016;8:126-34.
11. Sekhon HK, Sircar K, Singh S, Jawa D, Sharma P. Determination of the biometric characteristics of palatine rugae patterns in Uttar Pradesh population: A cross-sectional study. Indian J Dent Res 2014; 25:331-5.
12. Dwivedi N, Nagarajappa AK. Morphological analysis of palatal rugae pattern in central Indian population. J Int Soc Prevent Communit Dent 2016;6:417-22.
13. Bharath ST, Kumar GR, Dhanapal R, Saraswathi TR. Sex determination by discriminant function analysis of palatal rugae from a population of coastal Andhra. J ForensicDent Sci 2011; 3:58-62.
14. Mustafa AG, Allouh M, Tarawneh I, Alrbata R. Morphometric analysis of palatal rugae among Jordanians: further evidence of worldwide palatal rugae individuality, Australian Journal of Forensic Sciences 2014;46(1):53-63
15. Kamla R, Gupta N, Bansal A, Sinha A, Palatal Rugae Pattern as an Aid for Personal Identification: A Forensic Study, JIAOMR 2011; 23(3):173-178.
16. Bhagwath S, Chandra L, Rugae pattern in a sample of population of Meerut - An institutional study. J Forensic Dent Sci 2014; 6:122.
17. Saraf A, Bedia S, Indurkar A, Degwekar S, Bhowate R. Rugae patterns as an adjunct to sex differentiation in forensic identification, J Forensic Odontostomatol. 2011; 29(1):14-9.
18. 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(6):470-473.
19. Azab SMS, Magdy R, Sharaf El Deen MA. Patterns of palatal rugae in the adult Egyptian population, Egypt J Forensic Sci 2016; 6: 78–83.
20. Kolude B, Akinyele A, Joshua OT, Ahmed L. Ethnic and gender comparison of rugae patterns among clinical dental trainees in Ibadan, Nigeria, Pan Afr Med J. 2016; 23:204.
21. Babu GS, Bharath TS, Kumar NG,Characteristics of palatal rugae patterns in west godavari population of India, J Clin Diagn Res.2013; 7(10):2356-9
22. Balgi P, Bhalekar B, Bhalerao K, Bhide E, Palaskar S, Kathuriya P. Study of palatal rugae pattern in gender identification. J Dent Allied Sci 2014;3:13-6.
23. Thabitha RS, Reddy RE, Manjula M, Sreelakshmi N, Rajesh A, Kumar VL. Evaluation of palatal rugae pattern in establishing identification and sex determination in Nalgonda children. J Forensic Dent Sci 2015;7:232-7.

24. Dawasaz AA, Dinkar AD, "Rugoscopy: predominant pattern, uniqueness and stability assessment in the Indian goan population," J Forensic Sci 2013;58(6):1621–27.
25. Basnet BB, Parajuli PK and Shakya R. A Study of Palatal Rugae Patterns in the Populations of Mongoloid and Tharu Ethnic Groups of Eastern Nepal. Austin J Anat. 2017; 4(2): 1067
26. Rath R, Reginald BA. Palatal rugae: An effective marker in population differentiation. J Forensic Dent Sci 2014; 6:46-50.
27. Shetty DK, Machale PS, Savant SC, Taqi SA. Comparison of palatal rugae patterns in Kodava and Malayalee populations of South India. J Forensic Dent Sci 2013; 5:85-9.
28. Kommalapati RK, Katuri D, Kattappagari KK, Kantheti LPC, Murakonda RB, Poosarla CS, Chitturi RT, Gontu SR, Baddam VRR. Systematic Analysis of Palatal Rugae Pattern for Use in Human Identification between Two Different Populations, Iran J Public Health 2017;46(5):602-607.
29. Saadeh M, Ghafari JG, Haddad RV, Ayoub F, Association Among Geometric Configurations of Palatal Rugae. J Forensic Odonstomatol 2017; 35(1): 33–34.