

# Quantitative and qualitative analysis of palatal rugae patterns in Gujarati population: A retrospective, cross-sectional study

Jayasankar Pillai,  
Alka Banker<sup>1</sup>,  
Amit Bhattacharya<sup>2</sup>,  
Radha Gandhi<sup>3</sup>,  
Nupur Patel<sup>3</sup>,  
Sarathak Parikh<sup>3</sup>

Departments of Oral Pathology  
and <sup>2</sup>Orthodontia, Government  
Dental College and Hospital,  
Ahmedabad, <sup>1</sup>Department of  
Orthodontia, Goenka Research  
Institute of Dental Sciences,  
Gandhinagar, <sup>3</sup>Consulting Dental  
Surgeon, Ahmedabad, Gujarat,  
India

## Address for correspondence:

Dr. Jayasankar Pillai,  
4-L-5 Shree Balaji Agora,  
S. P. Ring Road, Sughad,  
Gandhinagar - 382 424,  
Gujarat, India.  
E-mail: jppillaigdc@gmail.com

## Abstract

**Introduction:** Palatal rugae are irregular and nonidentical mucosal elevations seen on the anterior third of palate. They are arranged in transverse direction on either side of the median palatine raphe (MPR) and are protected from high temperature and trauma because of their rational position in the oral cavity. Their number and patterns are not uniform in all the individuals, and they appear to vary in different population subsets. The study of palatal rugae is termed as "Rugoscopy" or "Palatoscopy", and it finds its application in various fields such as anthropology, orthodontics, forensic sciences; including forensic odonto-stomatology. **Aim:** The aim of this study was to evaluate the quantitative and qualitative parameters of palatal rugae using pre-orthodontic study models of Gujarati samples. **Objectives:** (1) To identify the predominant palatal arch forms in the study samples. (2) To evaluate and correlate the rugae count in both male and female samples with the different palatal arch forms. (3) To assess the symmetry and/or asymmetry in rugae count between the right and left side. (4) To analyze and correlate the qualitative characters such as size, shape, direction, and unification in male and female study samples. **Materials and Methods:** One hundred pre-orthodontic maxillary dental stone casts of patients with an age range of 17–25 years were selected. The outlines of the rugae were traced using microtip graphite pencil and examined using magnifying glass for different patterns. The quantity and quality of rugae patterns were recorded according to Thomas et al. classification and the data were statistically analyzed by the statistician using SPSS program. **Results:** Overall, 962 rugae were observed in the study sample. The mean rugae count was 9.86 in males and 9.38 in females. The left side rugae count was more than the right side in both the sexes and it was not statistically significant. Fifty-six percent of the samples showed asymmetry in rugae count between the right and left. Class B palatal arch form was the most common type in the study samples. The number of primary rugae count was more in both the sexes. The distribution of straight (40.2%) and curved (40.4%) types of rugae were almost equal in males but in females, the straight rugae pattern (42.2%) was more than the curved (36.9%), followed by wavy and circular. Of 962 rugae, 36.4% were of horizontal type followed by forward (33.4%) and backward (29.2%). About 1 % of rugae showed

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

**For reprints contact:** reprints@medknow.com

**How to cite this article:** 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.

## Access this article online

### Website:

www.jfds.org

### DOI:

10.4103/0975-1475.195110

### Quick Response Code



perpendicular pattern and only 9.25% showed unification pattern and the divergent type of unification was more common than the convergent type. **Conclusion:** There is no gender discrimination in relation to any of the metric or non-metric parameters of the palatal rugae in this study samples. No two samples showed similarity in the distribution of palatal rugae patterns. The straight and horizontal rugae distributions were predominant in our Gujarati Study samples.

**Key words:** Gender discrimination, mid-palatine raphe, palatal rugae, symmetry

## Introduction

“Rugae” are an anatomical term which refers to a series of ridges produced by folding of the wall of an organ. In the oral cavity, they are seen as irregular elevated ridges on the mucous membrane covering the anterior part of the hard palate. They radiate somewhat transversely from the incisive papilla and the anterior part of the palatine raphe on either side.<sup>[1]</sup> They are supported laterally by a submucosal cushion of adipose tissue, thus forming a fatty antero-lateral region. The lining epithelium is of stratified squamous type with an underlying dense collagenous connective tissue.<sup>[2]</sup> The study of palatine rugae is known as “Palatal Rugoscopy” or “Palatoscopy” and was first proposed by a Spanish investigator, Trobo Hermosa in 1932.<sup>[3]</sup> It is a well-established fact that the rugae patterns are stable, and unique oral topographical structures to an individual, like his or her finger prints<sup>[4]</sup> and this characteristic pattern remains stable from the time of development till the oral mucosa degenerates at death. Both the quantity and quality of rugae are found to be unchanged throughout life; however, some authors have reported changes in the mean rugae count with age.<sup>[5]</sup> The rugae are located at a more secured position in the oral cavity, well bounded by cheek, lip, tongue, teeth, and alveolar process. Hence, they are well protected from trauma, extreme finger sucking in infancy, and persistent pressure with orthodontic treatment and dentures. The uniqueness, stability and the resistance to damage, facilitate palatal rugae as one of the important anatomical landmarks in forensic investigations.<sup>[6]</sup> Similarly, racial, ethnic, and geographical variations in the patterns also influence the identification of individuals, especially during a mass disaster and in the field of forensic anthropology.<sup>[7-9]</sup> The palatal rugae are classified and studied qualitatively using their length, shape, direction, and unification parameters and quantitatively on the number of rugae present on either side of the mid-palatine raphe. Several classifications of palatine rugae were proposed by researchers in the past using the metric and non-metric characteristics.<sup>[6,10,11]</sup> On an average, 3–6 rugae are present on either side of the median palatine raphe, and the number may or may not be same on both the sides. The length of an individual ruga is usually measured from its starting point near the mid-palatine raphe to its end point transversely. The length parameter classifies rugae patterns into:

- Primary rugae: 5–10 mm
- Secondary rugae: 3–5 mm
- Fragmentary rugae: <3 mm.

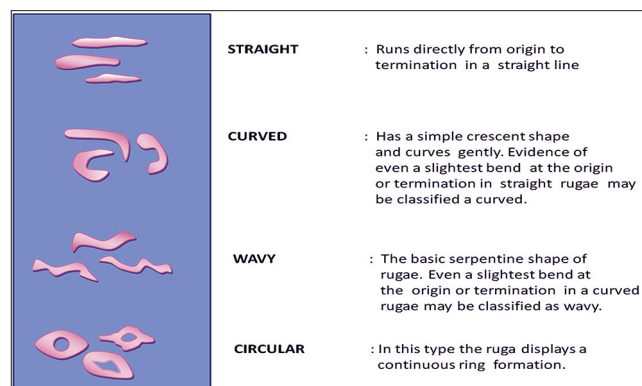
The shape of individual rugae usually fits in any of the following four major categories [Box 1].

- Straight
- Curved
- Wavy and
- Circular.

The direction pattern of each ruga is determined in relation to the mid-palatine raphe (MPR). The angle between the line joining the origin and termination of a ruga determines the direction pattern of that particular ruga. The forward directed rugae (F) are associated with positive angles, and the angles are negative for backward directed rugae (B). If the angle is zero, then the ruga is considered a horizontal (H) and ruga running parallel to MPR are considered as perpendicular (P) [Figure 1].

The term “Unification” is designated when two rugae are joined at their origin or insertion. Unifications in which two rugae begin from the same origin, but bifurcate transversely are considered as diverging (D) whereas rugae with different origins which are joined on their lateral positions are considered as converging (C) [Figure 2].

Several studies were done in the past with the objective of investigating the pattern distribution, gender discrimination, and ethnic, or geographical variations as research parameters in the field of anthropology, anatomy, forensic



**Box 1:** The classification of rugae according to various shapes

odontology, orthodontics, and prosthodontics.<sup>[10-14]</sup> Here, we designed this study to explore the unique patterns of palatal rugae in Gujarati population using the quantitative and qualitative data, gathered through 100 pre-orthodontic dental casts. One of our objectives was also to compare the distribution of rugae patterns with palatal arch forms.

## Materials and Methods

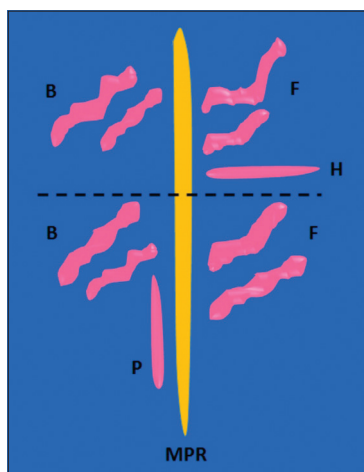
This study was aimed at the analysis of a sample which is representative of Gujarati Population. Therefore, individuals whose mother tongue is not Gujarati and who are not of Gujarati origin were excluded to get a homogeneous study sample. The individuals, whose casts were selected for this study, were of different social classes and from various geographical regions of Gujarat. All these individuals underwent orthodontic treatment, and their pre-orthodontic dental casts were utilized for this study. Casts of cleft palate and maxillary expansion cases were excluded from this study. Pre-orthodontic maxillary casts of 50 males and 50 females

whose age ranged from 17 to 25 years were selected, and the rugae were delineated using 0.1  $\mu$  tip HB pencil to enhance their visualization [Figure 3]. The mid-palatal raphe was identified, and the number of rugae on the right and left of it was noted down. Each ruga, on the right and left of MPR, was assigned a number (such as 1, 2, 3... 6) from the anterior to posterior [Figure 4]. The metric and non-metric characteristics of palatal rugae were noted down in the prescribed performa. As the degree of development of rugae is dependent on the growth of palatal arch, we for the first time, tried to compare the rugae patterns with the form of the palatal vault.

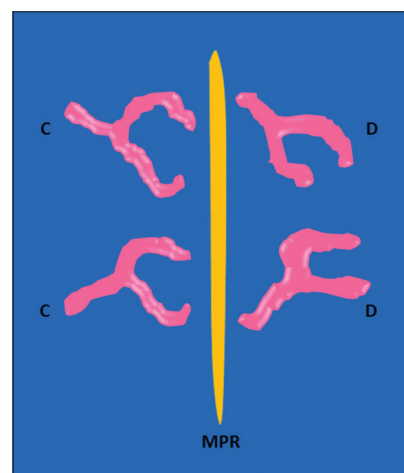
Accordingly three types of palatal forms were identified.

- Class A: Broad, shallow, and flat palate
- Class B: V-shaped, medium vaulted palate
- Class C: High vaulted and U-shaped palate.

Statistical analysis of the data obtained was done using SPSS Version 21.0 (IBM Corp. in Armonk, NY) by a qualified



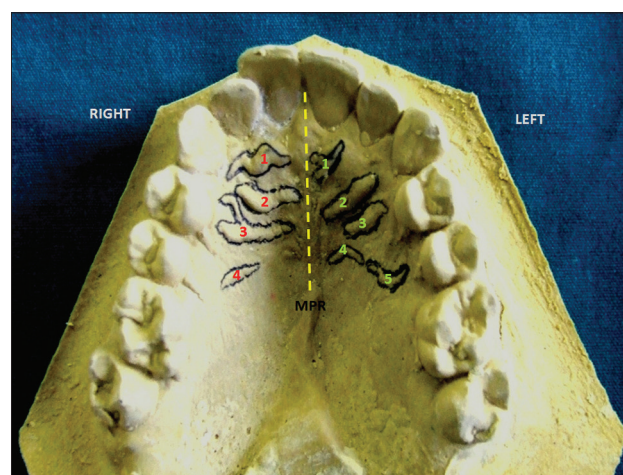
**Figure 1:** The direction patterns of palatal rugae in relation to the midpalatine raphe



**Figure 2:** The unification patterns of palatal rugae



**Figure 3:** The materials used in this study



**Figure 4:** The highlighted rugae patterns and their numbering for the quantitative analysis on either sides of mid-palatineraphae

statistician. Student's *t*-test was utilized to compare the mean values of two samples, and Chi-square test was done to analyze the significant difference between two groups of data.

## Results

After a thorough analysis of 100 study models, the following observations were noted.

### Palatal arch forms

The Class B form of the palate (52%) was the most predominant type, followed by Class A (26%) and Class C (22%) [Table 1]. In male samples, Class C was the least prevalent (14%) whereas in females it was Class A (26%). The distribution of the palatal arch forms however was not statistically significant ( $P = 0.126$ ).

### Number of rugae

Overall, 962 rugae with a mean value of 9.62 were observed in this study sample. The mean rugae count in the right side was 4.73 (standard deviation [SD] = 0.88) and in the left

side was 4.89 (SD = 1). There was no statistical significance between the mean rugae count between right and left side [Table 2]. The mean rugae count in male was 9.86, whereas for female it was 9.38. The difference in the mean rugae count between male and female was also not statistically significant [Table 3]. The quantitative analysis on the number of rugae in the right and left of MPR revealed a total count ranging from 6 to 12 rugae. Maximum of 12 rugae was observed in 18% of male and 16% of females. The least number of rugae count in male was 7, and it was present in 4 (8%) of male samples. In female, the least count of 6 rugae was seen in only one sample (2%). A maximum of 8 rugae count was observed in 19 female samples (24%) [Table 4]. In this study, 52% of males and 56% of females showed differences in the number of rugae between the right and left of MPR. The number of rugae was same on both the sides in 48% of male samples and in 44% of female samples. Overall, only 46% of the study sample showed symmetry in the number of rugae on the right and left sides. [Figure 5] When the palatal arch forms were compared for the quantitative distribution of rugae in both the genders, it was observed that the mean rugae count (right and left) was 10.23 for both males and females in Class A palatal form, 9.42 for Class B palate, and 9.36 for Class 3 palate form. The mean rugae count was more on the left side for Class A palate form, whereas, for Class B, and C palatal forms, it was more on the right side [Table 5]. Figure 6 shows the graphical representation of the difference in the mean rugae count between the right and left and in male and female samples and in all the three palatal arch forms are compared. There is greater difference in the mean rugae count between male and female samples; whereas the least difference in count is there between the right and left counts in female samples [Figure 6].

### Size of rugae

Primary rugae (>5 mm) constituted 84.9% of the total rugae count in our study samples. The mean value of primary rugae count in male samples was 34.14 for the right and 36.17 for the left side. Similarly, for females, it was 32.17 and 33.67 for the right and left, respectively. Furthermore, it was found that the primary rugae were more concentrated on the anterior

**Table 1: The distribution of palatal arch forms in male and female study samples. Note that Class B palatal form is more common in both genders**

	Palatal form (class)			Total	Chi-square P value	Significance
	A	B	C			
Gender						
Male						
Count	13	30	7	50	0.126	Not significant
Percentage within gender	26.0	60.0	14.0	100.0		
Female						
Count	13	22	15	50		
Percentage within gender	26.0	44.0	30.0	100.0		
Total						
Count	26	52	22	100		
Percentage within gender	26.0	52.0	22.0	100.0		

**Table 2: The total number of rugae count, its mean value, standard deviation, and significant differences between mean scores on the right and left sides in both male and female study samples**

Gender	Right			Left			Mean (right) – mean (left)	t	Significance
	Count	Mean (right)	SD	Count	Mean (left)	SD			
Male	240	4.8	0.83	253	5.06	0.93	–0.26	1.47	Not significant
Female	233	4.66	0.93	236	4.72	1.05	–0.06	0.3	Significant (0.01)
Total	473	4.73	0.88	489	4.89	1	–0.16	1.20	Not significant

SD: Standard deviation

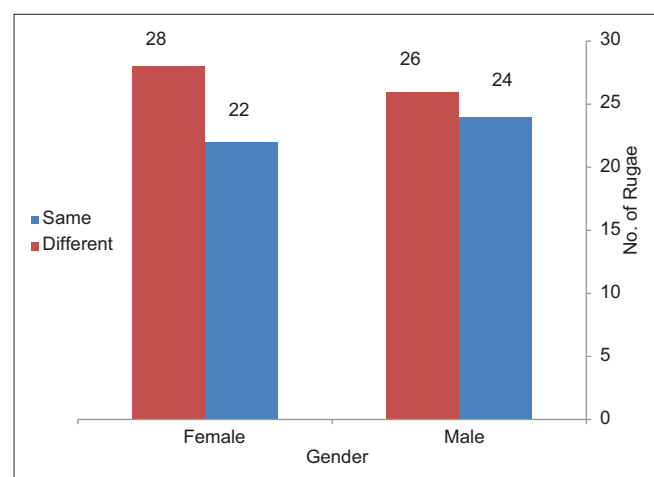
**Table 3: The mean rugae count in male and female samples**

Gender	Sample size	Mean rugae count	SD	Mean (male) – mean (female)	t	Significance
Male	50	9.86	1.57	0.48	1.48	Not significant
Female	50	9.38	1.67			

SD: Standard deviation



rugae, i.e., rugae number 1, 2, and 3 in both the genders. The secondary rugae count was more on the right side for male, whereas the count was more on the left side for female samples. The fragmentary rugae count was more on the left



**Figure 5:** The graphical representation of the symmetry and assymmetric distribution of number of palatal rugae on the right and left of MPR in both male and female samples

**Table 4:** The distribution of rugae count from minimum to maximum in both male and female samples

Gender	Total rugae present in the each palate (minimum 6 and maximum 12)							Sample size
	6	7	8	9	10	11	12	
Male								
Count	0	4	7	8	11	11	9	50
Percentage	0.00	8.00	14.00	16.00	22.00	22.00	18.00	100.00
Female								
Count	1	5	12	10	8	6	8	50
Percentage	2.00	10.00	24.00	20.00	16.00	12.00	16.00	100.00
Total								
Count	1	9	19	18	19	17	17	100
Percentage	1.00	9.00	19.00	18.00	19.00	17.00	17.00	100.00

**Table 5:** The rugae count in male and female samples among the 3 palatal arch forms

Palate form (class)	Rugae in male			Rugae in female			Total		Total count	t	Significance
	Right	Left	Total	Right	Left	Total	Right	Left			
A											
Count	63	70	133	66	67	133	129	137	266	1.32	Not significant
Mean	4.84	5.38	10.23	5.07	5.15	10.23	4.96	5.26	10.23		
SD	0.69	0.77	1.3	0.86	0.98	1.53	0.77	0.87	1.39		
B											
Count	145	150	295	95	100	195	240	250	490	0.92	Not significant
Mean	4.83	5	9.83	4.31	4.54	8.86	4.61	4.08	9.42		
SD	0.95	1.01	1.78	1.08	1.14	1.83	1.03	1.08	1.85		
C											
Count	32	33	65	72	69	141	104	102	206	0.42	Not significant
Mean	4.57	4.71	9.28	4.79	4.6	9.41	4.72	4.63	9.36		
SD	0.53	0.75	0.95	0.56	0.91	0.91	0.55	0.84	1.17		

SD: Standard deviation

side for male and reverse in case of females [Tables 6 and 7]. The quantity of secondary rugae was more in females than males, but the fragmentary rugae were slightly more in males than females, and they were seen more on the right side.

### Shape of rugae

Of the 962 rugae in both male and female, 41.2% were straight (S) type, 38.7% were curved type (Cu), 19.2% were wavy (W) type, and 0.9% were of circular (Ci) type [Figure 7]. About 40.2% of rugae in males and 42.2% of rugae in females were of straight type. The table is showing the distribution of shape pattern in male and female samples in right and left side is given below:

Side	Gender	
	Male	Female
Right	Cu>S>W>Ci	S>Cu>W>Ci
Left	S>Cu>W>Ci	Cu>S>W>Ci

### Direction of rugae

Tables 8 and 9 shows the distribution of each and every ruga according to the direction on both sides in male and female samples, respectively. When the direction of rugae was compared on either side, it was found that forward (F) direction rugae were more on the left side in both the genders. The backward (B) direction rugae were more concentrated on the right side in both the genders. Of 962 total rugae count, 350 rugae (36.4%) were of horizontal (H) type, followed by forward, backward, and perpendicular types [Figure 8]. The distribution of direction pattern of rugae in male and female samples on the right and left side is given below:

Side	Gender	
	Male	Female
Right	B>H>F>P	B>H>F>P
Left	F>H>B>P	F>H>B>P

### Unification of rugae

Only 8% of the rugae in males and 9.60% of rugae in females showed unification pattern [Figure 9]. In males, the left side

**Table 6: The distribution pattern of size of individual ruga on either sides of MPR in male samples**

Gender	Rugae number	Primary rugae		Secondary rugae		Fragmentary rugae		Total number of rugae
		Right	Left	Right	Left	Right	Left	
Male	Rugae 1	49	50	1	0	0	0	100
	Rugae 2	47	43	3	3	0	4	100
	Rugae 3	40	40	7	6	3	4	100
	Rugae 4	36	38	10	6	1	3	94
	Rugae 5	26	30	3	6	4	1	70
	Rugae 6	7	16	3	3	0	0	29
	Mean	34.17	36.17	4.50	4.00	1.33	2.00	82.17
	SD	15.66	11.84	3.33	2.45	1.75	1.90	28.53
	Total	205	217	27	24	8	12	493

SD: Standard deviation

**Table 7: The distribution pattern of size of individual ruga on either sides of MPR in female samples**

Gender	Rugae number	Primary rugae		Secondary rugae		Fragmentary rugae		Total number of rugae
		Right	Left	Right	Left	Right	Left	
Female	Rugae 1	49	49	1	1	0	0	100
	Rugae 2	42	46	6	3	2	1	100
	Rugae 3	41	40	5	9	4	1	100
	Rugae 4	38	36	2	7	4	1	88
	Rugae 5	19	18	8	7	2	1	55
	Rugae 6	4	13	5	2	1	1	26
	Mean	32.17	33.67	4.50	4.83	2.17	0.83	78.17
	SD	17.08	14.87	2.59	3.25	1.60	0.41	30.93
	Total	193	202	27	29	13	5	469

SD: Standard deviation

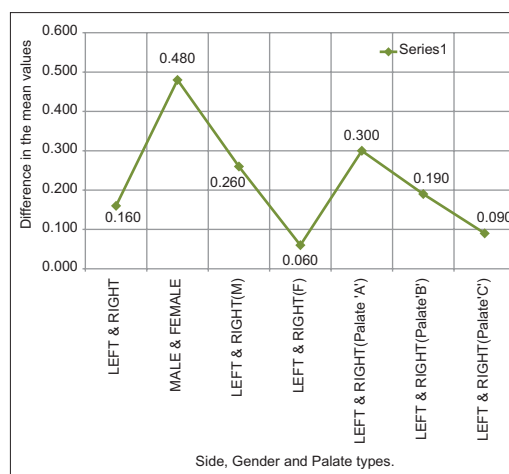
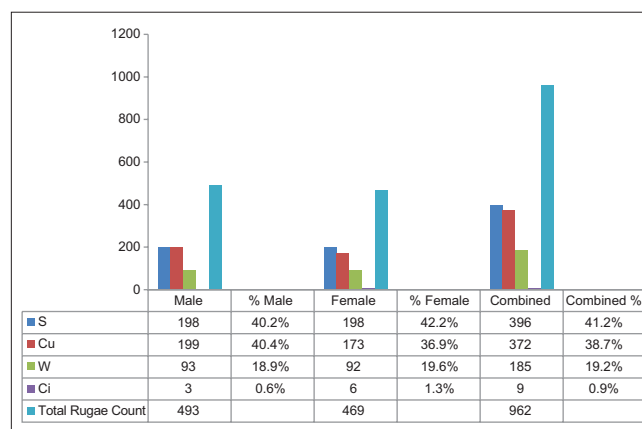
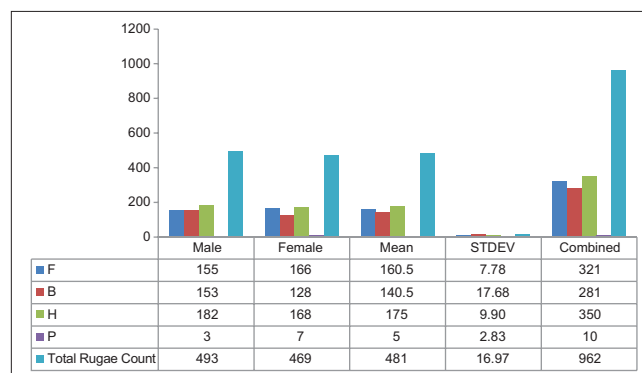
**Table 8: The distribution of each and every ruga according to the direction on both the right and left side in male samples**

Gender	Side	Direction of rugae	Rugae number (from anterior to posterior)						Total
			1	2	3	4	5	6	
Male	Right	Forward	15	9	9	6	3	2	44
		Backward	12	26	25	26	21	6	116
		Horizontal	23	15	16	14	9	2	79
		Perpendicular	0	0	0	1	0	0	1
		Total	50	50	50	47	33	10	240
	Left	Forward	23	23	28	20	13	4	111
		Backward	3	5	4	12	7	6	37
		Horizontal	23	21	18	15	16	10	103
		Perpendicular	1	1	0	0	0	0	2
		Total	50	50	50	47	36	20	253

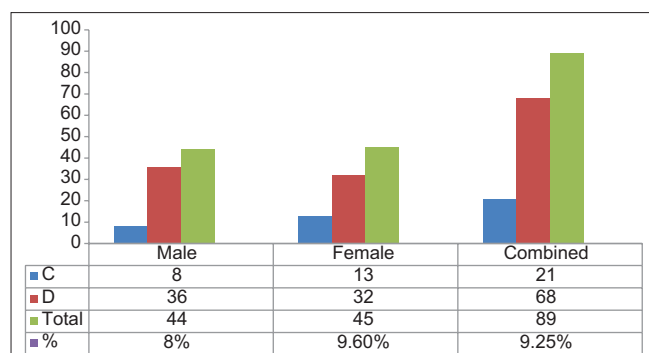
showed more unification than the right side, whereas in females, the right side showed more unification than the left side. About 76.4% of rugae unification was of divergent (D) type while the remaining 23.6% showed converging (C) pattern.

## Discussion

Palatal rugae patterns, from a forensic point of view, are used primarily to establish a person's identity and to know his/her ethnic


**Figure 6:** The graphical representation of differences in the mean values of palatal rugae when compared between sides, gender, and arch forms

**Figure 7:** The distribution of various shapes of rugae in male and female samples

**Figure 8:** The distribution of rugae according to their direction in male and female samples

origin. This study was designed after a thorough literature review on palatal rugae. Regional variations in the palatal rugae patterns in male and females were reported by several investigators in the past, but there was a scarcity of articles comparing the rugae count on the right and left of the MPR and also its significance with the palatal arch forms. Our study like many other earlier studies [Table 10] revealed that rugae pattern did not comprise one type



**Figure 9:** The distribution of unification pattern of palatal rugae in male and female samples

**Table 9: The distribution of rugae according to their direction in female samples**

Gender	Side	Direction of rugae	Rugae number						Total
			1	2	3	4	5	6	
Female	Right	Forward	13	12	10	8	2	2	47
		Backward	10	18	24	22	18	4	96
		Horizontal	27	20	16	14	9	4	90
		Perpendicular	0	0	0	0	0	0	0
		Total	50	50	50	44	29	10	233
	Left	Forward	25	25	27	24	13	5	119
		Backward	5	4	4	7	5	7	32
		Horizontal	20	18	18	13	6	3	78
		Perpendicular	0	3	1	0	2	1	7
		Total	50	50	50	44	26	16	236

**Table 10: Some of the population based studies on palatal rugae**

Authors	Year	Population studied
Shetty <i>et al.</i> <sup>[9]</sup>	2005	Mysore versus Tibetan
Nayak <i>et al.</i> <sup>[10]</sup>	2007	Western India versus South India
Arora <i>et al.</i> <sup>[15]</sup>	2008	Karnataka versus Manipur
Paliwal <i>et al.</i> <sup>[16]</sup>	2010	Madhya Pradesh versus Kerala
Gondivkar <i>et al.</i> <sup>[17]</sup>	2011	Western India
Jibi <i>et al.</i> <sup>[18]</sup>	2011	Davangree
Bharath <i>et al.</i> <sup>[19]</sup>	2011	Costal Andhra
Kamala <i>et al.</i> <sup>[14]</sup>	2011	Lucknow
Kallianpur <i>et al.</i> <sup>[24]</sup>	2011	Indian versus Nepalese
Surekha <i>et al.</i> <sup>[20]</sup>	2012	Manipur versus Kerala
Shanmugam <i>et al.</i> <sup>[21]</sup>	2012	South Indian versus North Indian
Babu <i>et al.</i> <sup>[22]</sup>	2013	West Godavari
Bhagwath and Chandra <sup>[13]</sup>	2014	Meerut
Byatnal <i>et al.</i> <sup>[23]</sup>	2014	Andhra Pradesh, Tamil Nadu, Karnataka, Madhya Pradesh, Maharashtra

alone, but a mixture of various patterns. The mean rugae count in our study was 9.86 and 9.38 in males and females, respectively. A similar study<sup>[13]</sup> done in Meerut population revealed a mean rugae count of 7.04 and 6.8 in males and females, respectively. Similar to our study, there was no statistical difference between the rugae count in male and female sample in their study. In a Lucknow population study,<sup>[14]</sup> the mean rugae count in males was 8.86 and in females was 8.53, and there was no statistical

significance in rugae count between males and females and between right and left sides in that study too. Similarly, in an Andhra population study, there was no statistical significance in the number of rugae between males and females.<sup>[19]</sup> A comparative analysis of rugae patterns between Indian (Mysore population) and Tibetan population by Shetty *et al.*<sup>[9]</sup> revealed that Indian males had more primary rugae on the left side than females, and the reverse was seen in Tibetan population. They also reported that Indian males had more number of curved rugae on both right and left side than Tibetan males, whereas Tibetan females had greater number of wavy rugae on both sides than Indian females. Kallianpur *et al.*<sup>[24]</sup> compared the patterns in Indian and Nepalese population and reported that the mean rugae count was greater in Indians, and the wavy rugae were predominant in both races followed by curved type in Indian samples and straight type in Nepalese samples. A statistically significant difference in total number of rugae between the two sexes in the West Indian Population was reported by Gondivkar *et al.*<sup>[17]</sup> whereas in our study and also from the studies done by Kapali *et al.*<sup>[25]</sup> Fahmi *et al.*<sup>[26]</sup> Jibi *et al.*<sup>[18]</sup> Saraf *et al.*<sup>[27]</sup> and Kamala *et al.*<sup>[14]</sup> there was no such significance. Kapali *et al.* in Aboriginal samples also showed insignificant differences in rugae count between right and left in both the sexes. Hence, we can assume that the quantitative parameter does not contribute much for the sexual dimorphism in rugae. Furthermore, the discriminant function analysis of palatal rugae using length and shape parameters for gender determination yielded an accuracy of only 73.08% in a Coastal Andhra population study.<sup>[19]</sup> Nayak *et al.*<sup>[10]</sup> in their Indian sample study, also showed more number of rugae on the right side, whereas in our study, the number of rugae was more on the left side. The wavy and curved rugae were more predominant in their study while curved and straight patterns dominated in our study. The mean rugae count as observed in samples from Chile was 12.27, and the most prevalent rugae shapes were sinuous and curved types. This finding was similar to the study by Nayak *et al.* A comparative study of palatal rugae in populations of 5 different states in India by Byatnal *et al.*<sup>[23]</sup> showed predominant wavy pattern followed by straight in Andhra, Karnataka, Madhya Pradesh, and Maharashtra population. In Tamil Nadu population, the wavy pattern was followed by curved type of rugae. In our sample (Gujarati Population), we found the predominance of straight rugae followed by curved one. The mean value of number of rugae in females was slightly higher than that of the males in a Nigerian population study,<sup>[28]</sup> which was reversed in our findings. Indian studies by Sharma *et al.*<sup>[29]</sup> and Nayak *et al.*<sup>[10]</sup> showed wavy and curved rugae forms as predominant patterns in their study samples. However, a study by Rai and Anand<sup>[30]</sup> showed that North Indian population had a predominance of straight pattern. Their findings were similar to our study but were contrary to the study by Shanmugam *et al.*<sup>[21]</sup> Although the palatal rugae patterns do not possess any gender-based differences, the discriminatory ability in population differentiation showed an accuracy of 93.5%<sup>[31]</sup> and 70%<sup>[10]</sup> in Indian Population studies. According to Saraf *et al.*<sup>[27]</sup> the quantity of rugae did not show any gender variation; however, the logistic regression analysis

of rugae shape (one of the qualitative parameters) enabled high accuracy in gender predilections (>99%). A study<sup>[16]</sup> comparing the rugae of Madhya Pradesh and Kerala populations showed a significant predominance of straight type on the right side in the former population samples while in the latter the wavy pattern was common. In their study, there was no significance in the rugae shape in female subjects. A West Godavari population study<sup>[22]</sup> revealed insignificant result in the distribution of shapes of rugae while the distribution of unification pattern showed significant difference among gender. In our study, there was no significance in the gender distribution of the unification patterns. Shetty *et al.*<sup>[32]</sup> showed a significant difference between Malayalees and Kodavas population for wavy and unification patterns. They reported 100% distribution of wavy patterns in Kodavas, whereas in our Gujarati population, the curved and straight patterns dominated over wavy types. The Malayalees population in their study showed significant differences between sexes for straight rugae which were insignificant in our study. About 56.7% of Malayalees and 43.3% of Kodavas showed unification pattern while in our study, unification was observed in only 9.27%. A significant difference in unification pattern among genders was also observed in Coastal Andhra population.<sup>[19]</sup> Similar Indian study<sup>[15]</sup> between Karnataka and Manipur populations also showed significant differences in the rugae patterns. Another Indian study,<sup>[20]</sup> comparing the rugae shape of Manipuri and Kerala populations showed statistically significant association which was lacking in our study. In contrast to our study, their female samples showed more rugae than the males; however, the quantitative predominance on the left side was similar to our finding. Thus from the majority of the studies, it is observed that palatal rugae patterns vary between different population groups, and there is no significant sexual dimorphism in relation to the quantitative and qualitative parameters of palatal rugae.

## Conclusion

Palatal rugae are anatomical structures with clinical, forensic, and anthropological significances. Through literature analysis, it is evident that there is no quantitative significance among genders. Based on the rugae patterns alone, population identification also becomes difficult as similar patterns are seen in different population groups. Further studies on larger sample size are required to validate the role of palatal rugae in forensic identification and gender discrimination. However, with the availability of ante-mortem records of the palatal rugae, the forensic investigators might face fewer challenges in identification of burn victims or a person in case of mass disasters.

## Acknowledgment

The authors thank Dr. Falguni Mehta, Prof. and Head Department of Orthodontia, Dr. Renuka A. Patel, Assistant Professor, Department of Orthodontia for their departmental support in carrying out this study and Mr. Kamal for his statistical help.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

## References

- Berkovitz BK, Holland GR, Moxham BJ. Oral Anatomy, Histology and Embryology. 3<sup>rd</sup> ed. London: Mosby; 2002. p. 4.
- Nanci A. Tencate's Oral Histology: Development, Structure and Function. 6<sup>th</sup> ed. London: Mosby; 2003. p. 363.
- Pueyo VM, Garrido BR, Sánchez JS. Odontología Legally Forense. Vol. 23. Masson: Barcelona; 1994. p. 277-92.
- English WR, Robison SF, Summitt JB, Oesterle LJ, Brannon RB, Morlang WM. Individuality of human palatal rugae. J Forensic Sci 1988;33:718-26.
- Hauser G, Daponte A, Roberts MJ. Palatal rugae. J Anat 1989;165:237-49.
- Lysell L. Plicae palatinae transversae and papilla incisiva in man; a morphologic and genetic study. Acta Odontol Scand 1955;13 Suppl 18:5-137.
- Venegas VH, Valenzuela JS, López MC, Galdames IC. Palatal rugae: Systematic analysis of its shape and dimensions for use in human identification. Int J Morphol 2009;27:819-25.
- Thomas CJ, Kotze TJ. The palatal ruga pattern in six southern African human populations. Part II: Inter-racial differences. J Dent Assoc S Afr 1983;38:166-72.
- Shetty SK, Kalia S, Patil K, Mahima VG. Palatal rugae pattern in Mysorean and Tibetan populations. Indian J Dent Res 2005;16:51-5.
- 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.
- Thomas CJ, Kotze TJ. The palatal ruga pattern: A new classification. J Dent Assoc S Afr 1983;38:153-7.
- Shukla D, Chowdhry A, Bablani D, Jain P, Thapar R. Establishing the reliability of palatal rugae pattern in individual identification (following orthodontic treatment). J Forensic Odontostomatol 2011;29:20-9.
- Bhagwath S, Chandra L. Rugae pattern in a sample of population of Meerut – An institutional study. J Forensic Dent Sci 2014;6:122-5.
- Kamala R, Neha G, Amol B, Abhishek S. Palatal rugae patterns as an aid for personal identification: A forensic study. Indian J Oral Med Radiol 2011;23:173-8.
- Arora V, Bagewadi A, Keluskar V, Shetti A. Comparison of palatal rugae patterns in two populations of India. Int J Med Toxicol Legal Med 2008;10:55-8.
- Paliwal A, Wanjari S, Parwani R. Palatal rugoscopy: Establishing identity. J Forensic Dent Sci 2010;2:27-31.
- Gondivkar SM, Patel S, Gadgil AR, Gaikwad RN, Chole R, Parikh RV. Morphological study of the palatal rugae in western Indian population. J Forensic Leg Med 2011;18:310-2.
- Jibi PM, Gautam KK, Basappa N, Raju OS. Morphological pattern of palatal rugae in children of Davangere. J Forensic Sci 2011;56:1192-7.
- 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.
- Surekha R, Anila K, Reddy VS, Hunasgi S, Ravikumar S, Ramesh N. Assessment of palatal rugae patterns in Manipuri and Kerala population. J Forensic Dent Sci 2012;4:93-6.



21. Shanmugam S, Anuthama K, Shaikh H, Murali K, Suresan V, Nisharudeen K, *et al.* Palatal rugae in population differentiation between South and North Indians: A discriminant function analysis. *J Forensic Dent Sci* 2012;4:75-9.
22. Babu GS, Bharath TS, Kumar NG. Characteristics of palatal rugae patterns in West Godavari population of India. *J Clin Diagn Res* 2013;7:2356-9.
23. Byatnal A, Byatnal A, Kiran AR, Samata Y, Guruprasad Y, Telagi N. Palatoscopy: An adjunct to forensic odontology: A comparative study among five different populations of India. *J Nat Sci Biol Med* 2014;5:52-5.
24. Kallianpur S, Desai A, Kasetty S, Sudheendra U, Joshi P. An anthropometric analysis of facial height, arch length, and palatal rugae in the Indian and Nepalese population. *J Forensic Dent Sci* 2011;3:33-7.
25. Kapali S, Townsend G, Richards L, Parish T. Palatal rugae patterns in Australian aborigines and Caucasians. *Aust Dent J* 1997;42:129-33.
26. Fahmi FM, Al-Shamrani SM, Talic YF. Rugae patterns in a Saudi population sample of males and females. *Saudi Dent J* 2001;13:92-5.
27. 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;29:14-9.
28. Dennis EO. Palatal rugae patterns of hobos in Abraka, South – Southern Nigeria. *Int J Morphol* 2012;30:70-9.
29. Sharma P, Saxena S, Rathod V. Comparative reliability of cheiloscopy and palatoscopy in human identification. *Indian J Dent Res* 2009;20:453-7.
30. Rai B, Anand SC. Palatal rugae: In forensic examination. *Indian Internet J Forensic Med Toxicol* 2007;5:14-6.
31. Rath R, Reginald BA. Palatal rugae: An effective marker in population differentiation. *J Forensic Dent Sci* 2014;6:46-50.
32. 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.