



TO STUDY PALATAL RUGAE PATTERN AND IDENTIFY ITS RELATIONSHIP TO MAXILLARY CANINE AND PRE-MOLAR POSITIONING AND GENDER IDENTIFICATION

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ABSTRACT

Palatal rugae which is also known as transverse palatine folds or plica palatinae are arranged in transverse direction from the mid-palatal raphe located in mid-sagittal plane. Palatal rugae is one of the stable landmark with diversification of pattern and due to its morphological and anatomical characteristics it can be used in same way as finger prints for human identifications. Palatine rugae are important as it can be useful in many ways. Palatal rugae possess features of an ideal forensic parameter - uniqueness, post-mortem resistance, and stability. Moreover, their anatomical positioning inside the mouth keeps them well protected from trauma and high temperatures as well as stable under severe burn cases, unaltered by chemicals like nicotine, ethanol, acetyl salicylate and physical irritants. Palatal rugae pattern in different ethnic groups may differ. Preserving natural appearance in edentulous patients is a challenge. This can be done by proper teeth arrangement as per the natural positioning of the teeth. Palatine rugae can be used as a potential reference to determine canine and other teeth position, which in turn will be useful for teeth arrangement in complete denture. So the study was carried out to determine the role of palatine rugae in maxillary canine positioning as well as for gender identification.

KEYWORDS: Palatine Rugae, Human Identification, Maxillary Canine, Teeth Arrangement

Palatal rugae which is also known as transverse palatine folds or plica palatinae are arranged in transverse direction from the mid-palatal raphe located in mid-sagittal plane. According to GPT 9 Palatal rugae is defined as – “An anatomic fold or wrinkle-usually used in the plural sense; the irregular fibrous connective tissue ridges located in the anterior third of the hard palate”. (GPT 9, 2017) (Shukla *et al.*, 2011)

Palatal rugae is one of the stable landmark with diversification of pattern and due to its morphological and anatomical characteristics it can be used in same way as finger prints for human identifications.

One of the important factors in producing natural appearance in edentulous patient is tooth position. Proper positioning of teeth is functional as well as aesthetically pleasing. (Winslow, 1732) (English *et al.*, 1988) (Caldas *et al.*, 2007) (Patil *et al.*, 2008) (Bhullar *et al.*, 2011) (Indira *et al.*, 2012) (Sekhon *et al.*, 2014) (Aruna *et al.*, 2015)

Many important anatomical landmarks decide the position of teeth. For example; Incisive papilla - for central incisor, Canine eminence – for canine, Maxillary tuberosity – 3rd molar in the maxillary arch.

Palatal rugae possess features of an ideal forensic parameter - uniqueness, post-mortem resistance, and stability. Moreover, their anatomical positioning inside the mouth keeps them well protected from trauma and high temperatures as well as stable under severe burn cases, unaltered by chemicals like nicotine, ethanol, acetyl salicylate and physical irritants (Patil *et al.*, 2008) (Balgı *et al.*, 2014) (Nallamilli *et al.*, 2015) (Sruthi *et al.*, 2016) (Saraf *et al.*, 2011) Along with these benefits, the use of palatal rugae as a forensic aid has added advantages because of their low utilization cost, simplicity, and reliability. They are also significant in dentulous patients and are proved to be the same before and after orthodontic treatment and remains stable after completion of growth thus emerging to be one of the reliable applications in forensic science. (Shukla *et al.*, 2011) (Zaki Mahross and Baroudi, 2015)

Palatal rugae patterns are sufficiently characteristic to discriminate between individuals. At the same time anatomical position of the rugae is such that they are protected inside the mouth by cheeks, lips, tongue, teeth, bone and buccal pad of fat from trauma and high temperature. They can be used in the same way as fingerprints for human identification. When identification of an individual by other methods as finger print, lip print

etc. is inconclusive, palatal rugae may thus be considered as an alternative source of information enabling the search field to be narrowed. According to some researchers, palatine rugae can be used for gender identification. (Almeida *et al.*, 1995) (Caldas *et al.*, 2007) (Patil *et al.*, 2008) (Aruna *et al.*, 2015)

Aesthetic tooth placement and physiological tooth arrangement are biological compatible and desired as end products of proper complete denture construction. Preserving a natural appearance is the most important part of treatment of every edentulous patient. One of the important factors in producing natural appearance in edentulous patient is tooth position. Proper placement of teeth should be functional as well as aesthetically pleasing. (Winslow, 1732)

Palatine rugae can be a reliable landmark in teeth arrangement particularly canine or premolar positioning. In horizontal plane the anterior teeth are aligned in relation to the inter-pupillary line and posterior teeth in relation to the ala-tragus line. Mostly under ideal conditions and ridge relations these anatomical landmarks will guide for the placement of artificial teeth as natural as possible. (Thomas and Kotze, 1983)

As very few studies are done to correlate palatal rugae to maxillary canine and premolar this study is done to find out the position of teeth in relation to the palatal rugae in natural dentition, which will guide us in the placement of the artificial teeth in the maxillary arch of edentulous patient. As two fingers are not alike in individual in the same way palatal rugae shows difference in the shape which in turn helps us in personal as well as gender identification.

MATERIALS AND METHODS

Study sample comprised a total of 80 subjects, on the basis of gender; Group 1 consisted of 40 males and Group 2 consisted of 40 females. This was approved by lead statistician.

Total 84 samples were taken considering 4 samples as error of doubt. The candidates were randomly chosen from the outpatient department of Prosthodontics and Crown & Bridge, AMC Dental College and Hospital, Khokhra. The candidates were chosen based on inclusion and exclusion criteria. Completely dentulous subjects with full complement of teeth till second molars were selected between the age group of 20-55 years. Subjects who were not willing for study, subjects having missing teeth (except for third molar), subjects with palatal deformity, palatal surgery, subjects with a history of orthodontic treatment or under ongoing orthodontic treatment, subjects with lesions causing mucosal or bony

changes in the maxillary anterior region were excluded from the study. Related approvals were taken from Head of Department of Prosthodontics and crown & bridge, Dean of AMC dental college and hospital and Institutional Review Board (IRB) prior to start of study. Written consent of all the subjects was taken. With the help of perforated metal stock tray, Alginate impressions of Maxillary arches were made for all subjects (figure-1). The impressions were sterilized with 2% glutaraldehyde. Then impressions were poured with Type III dental stone (Kalabhai product) (Figure-2). The base of the stone model was poured in base former to make parallel to the occlusal plane.

Dental models were obtained and outline of the palatal rugae were traced using a magnifying lens and a sharp graphite pencil under adequate light. All the quantitative measurements were calculated using electronic digital vernier calliper. The measurements were recorded. Similar procedure was followed for all the subjects. The shape, number, and length of rugae pattern were studied. Primary rugae with highest length were measured for all the subjects.

1. The length of primary rugae was measured using a Vernier Calliper in millimeters (mm) (Figure-3).

Length of the rugae was classified into-

- Primary >5mm
 - Secondary 3-5mm
 - Fragmentary <3mm and
2. Numbers of primary and secondary rugae were then calculated.
 3. In this study, the rugae patterns were recorded considering the classification given by Thomas and kotz in 1983 (Figure-4).

As per this classification

Shape classified into:-

- Curved
 - Wavy
 - Straight
 - Circular.
 - Unification
4. The relationship of rugae to canine was also studied. On the maxillary cast a midline was drawn which was coinciding with that of the mid palatine raphae extending from the incisive papillae to the posterior most extent of the rugae on the palate that was denoted as Line 'A'. This line divided the rugae in two halves and the rugae in each half were highlighted using a lead pencil under spot light. Second line was marked perpendicular from the midsagittal line passing from the most anterior point

of 1st palatine rugae and was extended to the associated maxillary anterior tooth which was denoted as line 'B'.

- The relationship of rugae to premolar was studied. On the maxillary cast a line was marked perpendicular to the midsagittal line passing from the most posterior point of the last palatine rugae and was extended to the associated maxillary posterior tooth which was denoted as line 'C'. (Figure-5)

Materials used for this study are perforated metal stock tray, Alginate (Tropicalgin; Zhermack) for impression making, Plastic bowl, Curved metal spatula, 2% glutaraldehyde as disinfectant, Type III dental stone (Kalabhai product), a digital Vernier calliper, a sharp graphite pencil, and Magnifying lens (Figure-6).



Figure 1: Alginate Impression of Maxillary arch

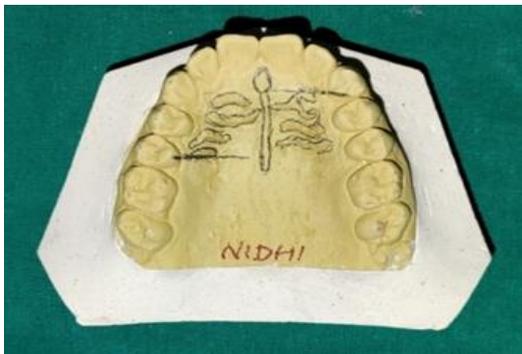


Figure 2: Maxillary Cast



Figure 3: Length of primary rugae was measured using a Digital Vernier Calliper in millimetres (mm)

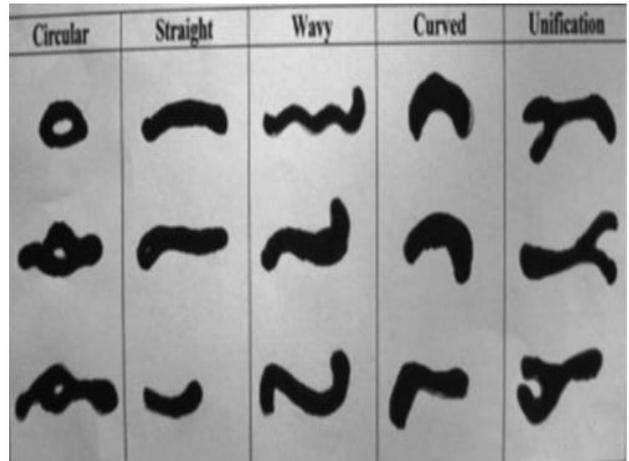


Figure 4: Thomas & Kotz classification

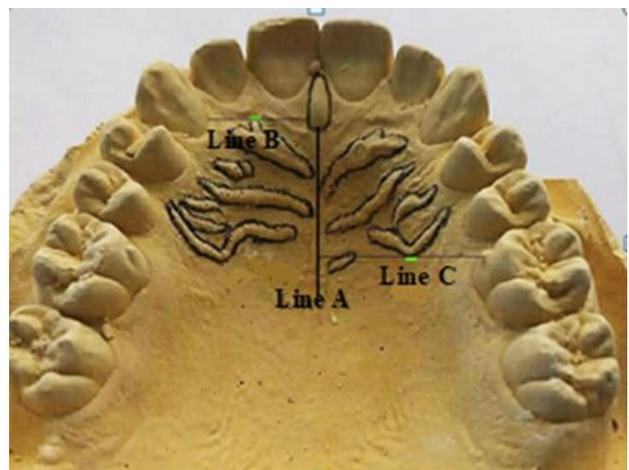


Figure 5: Maxillary Cast with marked Lines (Line A- Incisive papilla to the posterior most extent of the rugae on the palate; Line B- Perpendicular from the midsagittal line passing from the most anterior point of 1st palatine rugae; Line C- Perpendicular from the midsagittal line passing from the most posterior point of the last palatine rugae)



Figure 6: Armamentarium used for study

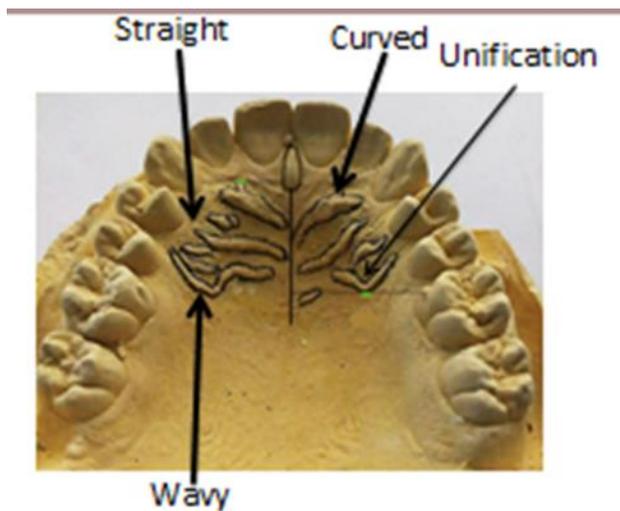


Figure 7: Different shape of palatal rugae pattern

STATISTICAL ANALYSIS

The Collected data was entered in Microsoft excel (2010) spreadsheet. The data on Continuous variable was presented in mean, standard deviation (SD) and standard error of mean and Discrete variable was presented as number and percentage. Normality assumption was tested using the Shapiro-Wilk test. Continuous groups were compared by Unpaired t-test/Mann-Whitney U test, Significance between two proportion were compared by Z test and Categorical groups were compared by Chi-square (χ^2) test. The entire data is statistically analysed using Statistical Package for Social Sciences (SPSS version 20.0, IBM Corporation, USA) for MS Windows. Probabilities of less than 0.05 and 0.01 were accepted as statistically significant and highly significant respectively.

RESULTS

It can be concluded that the average length of rugae was greater in males than females (males-13.78 mm females-12.85 mm) (Table-1) (Graph-1). Mann-Whitney U test showed significant difference in length of primary rugae between males and females.

It can be concluded that number of primary rugae of female was statistically significantly higher than male. Mann-Whitney U test showed significant difference in Number(s) of primary rugae between males and females. (Table-2) (Graph-2)

The shapes of the rugae recorded were as follows: Circular, straight, curved, wavy, and unification. Combinations of all the above mentioned shapes were seen in both the males and females (Table-3). Of all the shape patterns, wavy pattern was most commonly seen. The wavy pattern was more commonly seen in females and curved pattern in males. Z-test analysis showed significant difference in curved pattern in both males and females ($P < 0.05$) (Table-3).

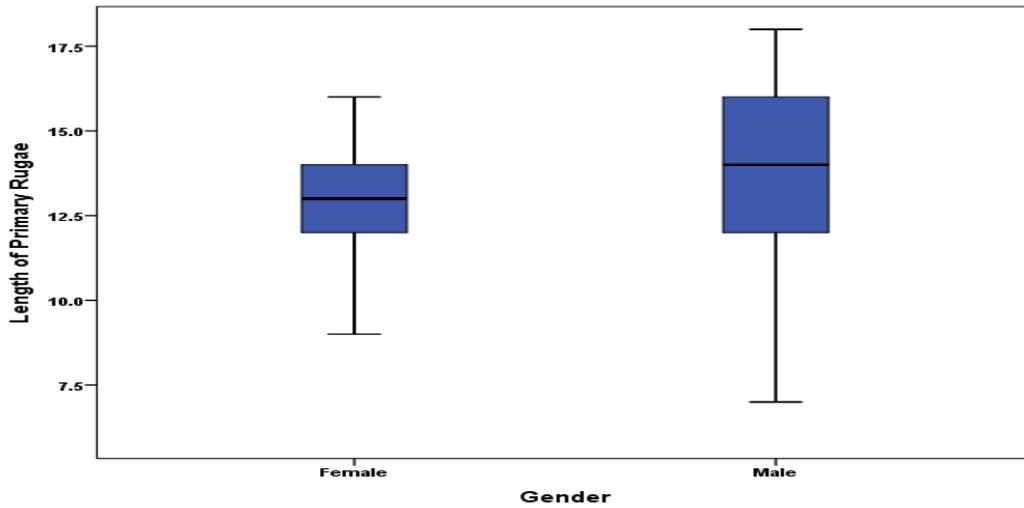
In this study the position of first palatine rugae with canine position were recorded. Maxillary Canine was divided in 3 parts- mesial 3rd, middle 3rd and distal 3rd. In 40 % males, 1st rugae was in line with mesial side of canine, in 57.5% male subjects, it was in association with middle of canine and only in 2.5% males the 1st palatine rugae was related to distal side of canine. But in females it was observed that in 72.5 % female subjects, 1st rugae was in line with mesial side of canine; while in 10% female subjects, it was in association with middle of canine, while in 10% female subjects, it was in association with distal side of canine in females. This canine positioning distribution is shown in Table 4 & Graph 3. Based on this result it was concluded that the relation of most anterior point of rugae is in mesial side in females while in middle in males.

The position of posterior most palatine rugae with maxillary 2nd Premolar position was recorded. Maxillary 2nd Premolar was divided in 3 parts- mesial 3rd, middle 3rd and distal 3rd. In 20 % males, 1st rugae was in line with mesial side of 2nd Premolar, in 47.5% male subjects, it was in association with middle of 2nd premolar and only in 32.5% males the 1st palatine rugae was related to distal side of 2nd premolar. But in females it was observed that in 5 % female subjects, 1st rugae was in line with mesial side of 2nd premolar; while in 22.5% female subjects, it was in association with middle of 2nd premolar, while in 72.5% females subjects, it was in association with distal side of 2nd premolar. This Maxillary 2nd premolar positioning distribution is shown in Table 5 & Graph 4. Based on this result it was concluded that the relation of most posterior point of rugae is in distal side in females while in middle 1/3rd in males.

Table 1: Distribution of Length of Rugae in Female and Male

Gender	N	Mean	SD	SEM	Mean Difference	SE of Mean Difference	p value [#]
Female	40	12.85	1.49	0.24	-0.92	0.41	<0.05
Male	40	13.78	2.15	0.34			

[#]: Unpaired t-test/Mann-Whitney U test

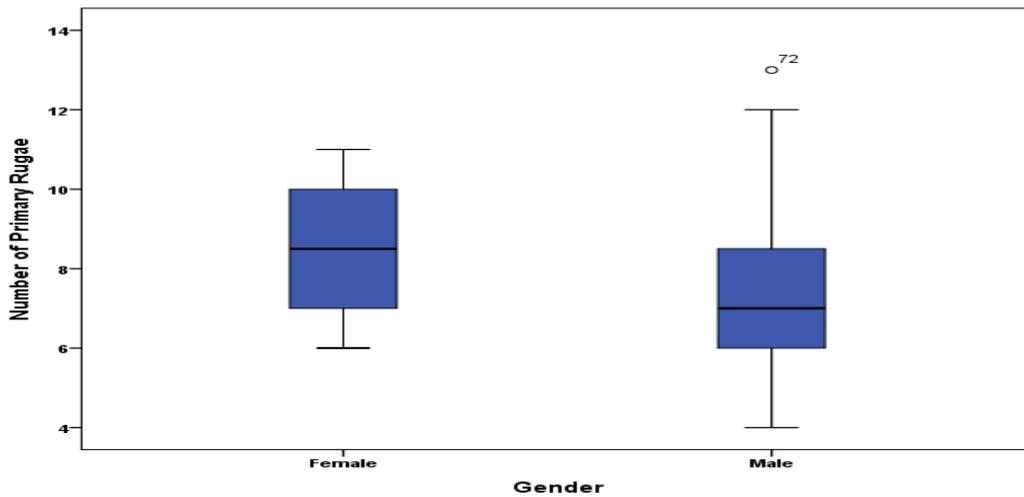


Graph 1: Shows the average length of rugae in males than females (males-13.78 mm females-12.85 mm)

Table 2: Distribution of Number of primary Rugae in Males and Females

Gender	N	Mean	SD	SEM	Mean Difference	SE of Mean Difference	p value [#]
Female	40	8.43	1.48	0.23	0.77	0.38	<0.05
Male	40	7.65	1.87	0.30			

#: Unpaired t-test/Mann-Whitney U test



Graph 2: Shows that the number of primary rugae of female was statistically significantly higher than male (Mean; Male- 7.65, Female- 8.45)

Table 3: Z test showing significance of predominant shape of rugae in female and male

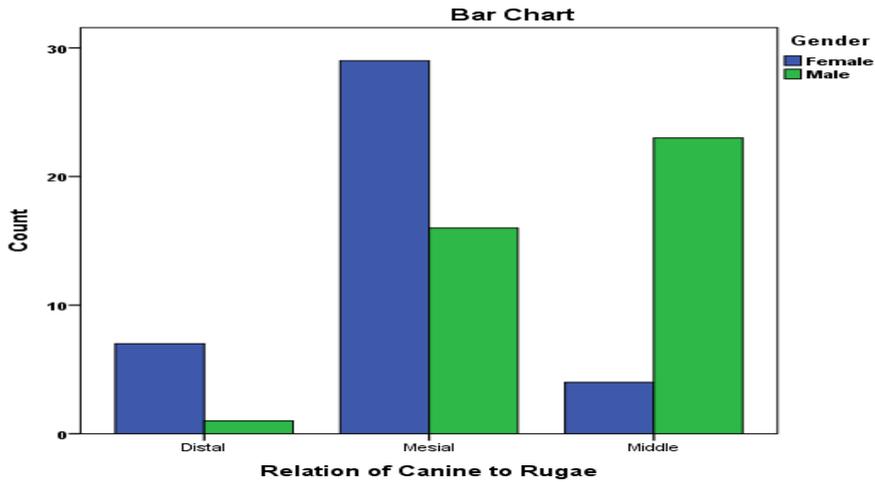
Predominant shape of rugae	Gender		P value ^{\$}
	Female (%) (n=40)	Male (%) (n=40)	
Curved	8 (20)	20 (50)	<0.01
Straight	6 (15)	5 (12.5)	>0.05
Unification	0 (0.0)	1 (2.5)	>0.05
Wavy	26 (65)	19 (47.5)	>0.05

\$: Z test

Table 4: Chi-Square test showing significance for relation of canine to rugae in female and male

Gender	Relation of canine to rugae			Total	p value *
	Mesial(%)	Middle(%)	Distal(%)		
Female	29(72.50)	4(10.00)	7(17.50)	40	<0.01
Male	16(40.00)	23(57.50)	1(2.50)	40	
Total	45(56.25)	27(33.75)	8(10.00)	80	

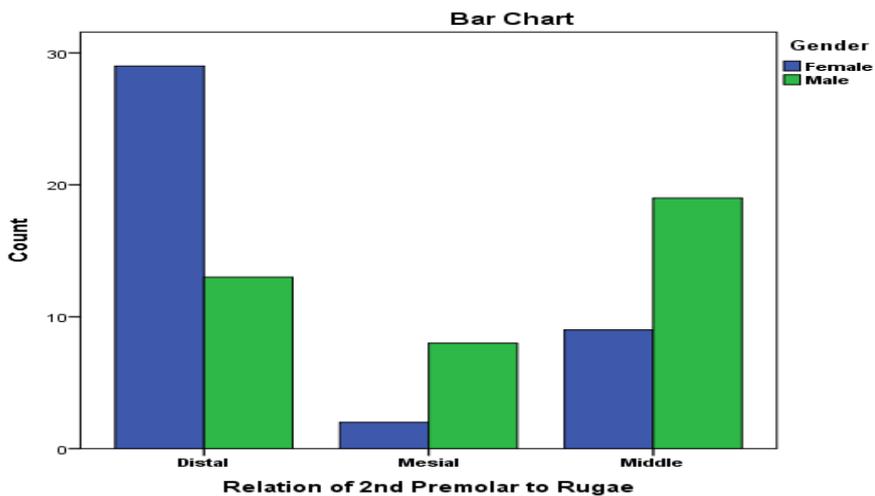
*: Chi-Square test



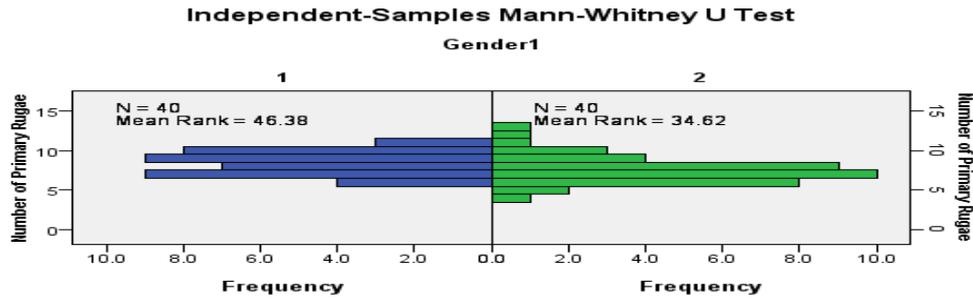
Graph 3: Shows relation of canine to rugae

Table 5: Chi-Square test showing significance for relation of 2nd premolar to rugae in female and male

Gender	Relation of 2 nd premolar to rugae			Total	p value *
	Mesial(%)	Middle(%)	Distal(%)		
Female	2(5.00)	9(22.50)	29(72.50)	40	<0.01
Male	8(20.00)	19(47.50)	13(32.50)	40	
Total	10(12.50)	28(35.00)	42(52.50)	80	



Graph 4: Shows relation of 2nd pre-molar to rugae



Total N	80
Mann-Whitney U	565.000
Wilcoxon W	1,385.000
Test Statistic	565.000
Standard Error	102.265
Standardized Test Statistic	-2.298
Asymptotic Sig. (2-sided test)	.022

Table 6: Distribution of Length of Rugae in Males and Females

Gender	N	Mean	SD	Mean Rank	Sum of Ranks	Mann-Whitney U test statistics	p value [#]
Female	40	12.85	1.49	35.13	1405	585	<0.05
Male	40	13.78	2.15	45.88	1835		

[#]: Mann-Whitney U test,

Table 7: Distribution of Number of primary Rugae in Males and Females

Gender	N	Mean	SD	Mean Rank	Sum of Ranks	Mann-Whitney U test statistics	p value [#]
Female	40	8.43	1.48	46.38	1855	565	<0.05
Male	40	7.65	1.87	34.83	1385		

[#]: Mann-Whitney U test

DISCUSSION

As two individuals are not alike in the same way palatal rugae of different individual shows variation in many ways. Palatal rugae own the features of an ideal forensic parameter such as uniqueness, post-mortem resistance, and constancy, facilitating personal identification procedures. Winslow (1732) was the first to describe them, while Santorini (1775) provided a diagrammatic illustration of rugae, depicting three continuous wavy lines that cross the midline of the palate. Gorla (1911) put forth the first system of palatal rugae classification, following which numerous classifications have come into existence. Palatoscopy or palatal rugoscopy is the study of palatal rugae in order to ascertain a person’s identity first proposed in 1932 by a Spanish investigator Trobo Hermosa. He considered it

secondary stress bearing areas for maxillary denture. It is not used only for personal identification but also for gender identification as well as useful anatomical landmark for canine or premolar positioning during maxillary teeth arrangement. It can be used in the same way as fingerprints. When identification of an individual by other methods as finger print, lip print etc. is inconclusive, palatal rugae may thus be considered as an alternative source of information.

Literature states no two palates to be alike in their configuration and even between twins, rugae patterns are said to be similar but not identical. Few authors reported the diversity of rugae patterns and their sex discrimination potential among different ethnic groups with varied results. Due to this uncertainty, this study was undertaken to identify the distinctiveness of the

palatal rugae patterns if any and to characterize this regional sample.

In our study, total 80 stone models were used as ante-mortem record due to simplicity in analysis. This study investigated differences in the length, number, and shape of rugae pattern, relationship of rugae to maxillary canine and maxillary second pre-molar in 40 males and 40 females visiting AMC Dental College and Hospital, Ahmedabad.

According to our study, the length of the palatal rugae was classified based on Thomas and Kots³ classification into primary, secondary and fragmentary rugae. On statistical analysis the average length of most predominant primary rugae was found to be greater in males than females. (Mean value for: males-13.78 mm and females-12.85 mm respectively). These findings were in accordance with some previous studies done by Pooja Balgi *et al.*, 2014 and contradicting those of Fahmi *et al.*, 2001 who reported that average length on right side in males was significantly less compared to the right side in females.

Based on this study, the numbers of primary rugae of female was statistically significantly higher than male. These findings were in accordance with some previous studies done by Bharath *et al.*, 2011, Surekha *et al.*, 2012, Dohke and Osato, 1994, Selvamani *et al.*, 2015 and contradicting those of Ali Reza Malekzadeh *et al.*, 2018, Pooja Balgi *et al.*, 2014 who reported that females were shown to have less number of rugae than males, which was statistically insignificant.

Based on this study, The shapes of the rugae recorded were as follows: Circular, straight, curved, wavy, and unification. Combinations of all the above mentioned shapes were seen in both the males and females (Table-3). Of all the shape patterns, wavy pattern was most commonly seen. The wavy pattern was more commonly seen in females and curved pattern in males. A study conducted by Nayak *et al.*, 2007, Kotrashetti *et al.*, 2011, Kumar *et al.*, 2012, Surekha *et al.*, 2012, Shanmugam *et al.*, 2012, Mohammed *et al.*, 2014, Bajracharya *et al.*, 2013, Kapali *et al.*, 1997. Showed the predominance of curved and wavy pattern of rugae in most population. Study conducted by Ibeachu *et al.* in Ikwerre ethnic group of Nigeria straight pattern was seen to be prevalent in both the genders (Graph 4) which was statistically significant more in females which was contradicting with our study.

Based on this study, the position of first palatine rugae with canine position was recorded. In 40 % males, 1st rugae was in line with mesial side of canine, in 57.5% male subjects, it was in association with middle of canine

and only in 2.5% males the 1st palatine rugae was related to distal 1/3rd of canine. But in females it was observed that in 72.5 % female subjects, 1st rugae was in line with mesial side of canine; while in 10% female subjects, it was in association with middle of canine, while in 10% female subjects, it was in association with distal side of canine in females. These findings were in accordance with previous study done by Dr.Sruthi *et al.* Also Grove and Christensen, 1988 did the study to determine relationship of the first palatine rugae to the maxillary canine in men observed that when a baseline was marked joining the distal contact points of maxillary canine, distance of the 1st palatine rugae were about 1mm anterior or posterior to the baseline.

Based on this study, the position of posterior most palatine rugae with maxillary 2nd Premolar position was recorded. In 20 % males, 1st rugae was in line with mesial side of 2nd Premolar, in 47.5% male subjects, it was in association with middle of 2nd premolar and only in 32.5% males the 1st palatine ruga was related to distal side of 2nd premolar. In a similar study Aruna Bhandari *et al.*, 2015 marked a point at distal most part of last rugae. They observed that the point when extended laterally it was in line with distal part of 2nd premolar and it concluded that it can be considered as a stable landmark for positioning the maxillary premolars.

CONCLUSION

This study showed uniqueness of palatal rugae. Every individual have a distinct but unique pattern. The study also demarcates importance of palatine rugae in maxillary canine and second pre-molar positioning during teeth arrangement. The present study showed individualistic nature of palatine rugae, so can be used for personal identification.

Following conclusions can be made from the present study:

1. The number of palatal rugae was found more in females than males.
2. The average length of rugae was greater in males than females.
3. In shape wavy pattern was most commonly seen among both groups. The wavy pattern was more commonly seen in females and curved pattern in males. Thus this finding helps in gender identification. Unification pattern was found in only one sample which was converging type. Circular were absent amongst all.
4. First palatine rugae can be considered as important anatomical landmark for maxillary canine positioning. In Males, 1st palatine rugae was in line

with middle of the maxillary canine while in females it coincided with mesial part of maxillary canine.

5. Last palatine rugae can be considered as important anatomical landmark for maxillary second pre-molar positioning. In Males, last palatine rugae was in line with middle of the maxillary second pre-molar while in females it coincided with distal part of maxillary second pre-molar.
6. Based on above findings present study also helps in selection of proper size of maxillary teeth in complete dentures.
7. Based on above findings present study also helps in proper positioning of maxillary teeth in complete dentures.

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