



## Sexual dimorphism using morphometric analysis of palatal features (Rugae Patterns, Palatal Dimensions, and Arch Type)

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### ABSTRACT-

**Background:** Identification of unknown dead bodies' especially through bony remains is done by various methods like DNA typing, Fingerprinting, Dental and other skeletal data, facial reconstruction, and rugae pattern study. Palatal rugae pattern or Rugoscopy yields a unique identification method in cases of skeletal remains due to its ability to resist even high temperatures, individuality, and stable nature throughout life.

**Duration and Place:** This study was conducted during the period of December 2022-April 2023 and samples were collected from the students of Annai Fathima College of Arts and Sciences, Madurai.

**Methods:** In this study, convenience random sampling was carried out on 100 (50 males and 50 females) study models (plaster casts) having 767 rugae patterns above 20 years of age. This study is based on the classification proposed by Thomas et al (1979). Dental casts were obtained and each cast was analyzed for rugae pattern and maxillary arch dimensions. Samples were categorized and differences were studied for uniqueness.

**Results:** Each individual had a different set of palatal rugae which are not the same, in all dimensions like length, shape, orientation, number, unification, and position. Males have higher numbers of rugae than females. Unification (convergence & divergence) was found to be more in females than males. In both sexes, the predominant shape and orientation category of rugae were found to be curved and forward respectively. The parameters of maxillary arch like arch width, arch length, and palatal index values were found to be higher in males as compared to females; however. The differences were found to be statistically significant. All three arch types were distributed in males and females yet the tapered arch type was the most prevailing in females whereas in males square arch type was the recurring type.

**Conclusion:** The palatal rugae pattern and maxillary palatal dimensions can be employed as an additional method in differentiating sex between human population groups.

**Keywords-** PR, maxillary palatal dimensions, dental casts, gender, forensics, personal identification, odontology

### Introduction:

Identification of unknown dead bodies' especially through bony remains is done by various methods like DNA typing, Fingerprinting, Dental and other skeletal data, facial reconstruction, and rugae pattern study. Palatal rugae pattern or Rugoscopy yields a unique identification method.

### Personal Identification :

Identification is the determination of the individuality of a person (the process of linking an unknown personal material) - a full corpse, skeleton, fingerprint, or biological fluid<sup>1</sup>. This detailed accumulation is very essential for the identification of individuals, and for demonstrating the civil rights of next of kin, especially in present-day scenarios when bombing blasts, flight crashes and other violent events

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are prevalent and external parts for identification are not available. At any time when an anonymous corpse is found, the individual is categorized into characteristic groups or masses and eventually, the different probabilities are narrowed down. This process may have two conclusions

1. Exclusion
2. identification.

#### **Corpus Delicti aka body of crime/essence of crime-**

Legal principles provide positive proof for the occurrence of any crime before convicting someone for committing that particular crime<sup>2</sup>. Materials that prove the occurrence of any such crime may include

- Dead body
- Photograph of a dead body
- Weapons
- Blood-stained clothes
- Blood stains on the Scene of the Crime, bullets, weapons, and several body parts.

#### **Alliance between Odontological exhibits and forensics-**

- Demonstrating an individual's identity is a complex procedure. Victim identification or matching in a catastrophe or crime scene seems to be the principal intention for personal, legal, and social reasons. Amidst the customary methods employed in the forensic sciences for assuring the identity of a person are fingerprinting, DNA analysis, and dental comparison.<sup>3</sup>
- Visual recognition is the most common and employed method for the reason that most deaths do not occur under unusual state of affairs, the remains are habitually done in visual identification.<sup>4</sup>
- In forensic dentistry, the oral cavity plays an essential role because of the distinctive anatomy of the teeth. In a few circumstances, if teeth are absent due to any reason, the most common of which is trauma, then the harness of human PR has been recommended as an alternative or unconventional method for identification and recognition.<sup>5</sup>
- The most customarily employed note or references for forensic identification are the human teeth, DNA matching, and fingerprints when visual identification of the individual is unclear. However, in situations where one or more of the above sources are inaccessible, it is

mandatory and certain to use an adjunct such as Rugoscopy or PR Analysis.

- The value of forensic dentistry in sex determination and individual identification is beyond debate. This is related to the suggested stability and individuality of the dental and palate structures including PR can be defined as a branch of dentistry that deals with the pertinent handling and examination of dental evidence and with the proper evaluation and presentation of dental findings in the interest of justice.

#### **Alliance between Anthropometric features in the human body and forensics**

Anthropometry (Bertillon system): the science which explains physical measures of a person's size, form, and functional capabilities<sup>6</sup>

It includes:

- Descriptive data: Color of hair, eyes, complexion, the shape of nose, ears, and chin.
- Body measurement: Height, AP diameter of head and trunk, a span of outstretched arms, length of middle finger, left little finger, left forearm, left foot, length, and breadth of right ear, and color of the left iris. (11 such measurements)
- Body marks, such as moles, scars, and tattoo marks
- Photographs of the front view and right profile of the head are also taken.<sup>7</sup>
- Based on the following categorization of palatal rugae and arch parameters study is been conducted-

#### **A. Thomas and Kotze classification**

1. Length of rugae – Based on the length of PR.
  - o Fragmentary -(<3mm)
  - o 2p -(3-5mm)
  - o 1p -(>5mm)
2. Shape of rugae- based on which shape the rugae is present.
  - o Curved- (a simple crescent shape with a gentle curve)
  - o Wavy- (snake-like shape-serpentine).
  - o Straight- (ran directly from origin to insertion)
  - o Circular- (definite continuous ring-like structure)



2. Unification-this type of rugae occurs when 2 rugae are joined at their origin or completion.

- o Converging- (2 rugae of different origins join at their lateral portion)
- o Diverging - (2 rugae had similar origins but branched immediately)

### B. Arch Parameters- (maxillary dimensions)

1. Arch type-Referring the image, the type of arch found in each maxillary cast is noted down based on "morphology classification by McLaughlin & Bennett (1997)" as shown in Fig 1 i.e.

- a. Square
- b. Oval
- c. Tapered

Computing the ratio of the dental arch, the type of arch in each maxilla is noted down for later analysis to correlate with other parameters.

1. Arch width-The distance between the buccal cusp of two molars of both the upper quadrants. With the help of digital calipers dimensions are computed as mentioned in the forthcoming image.
2. Palatal length-From the mid-point of the line joining the two molars of both quadrants to the incisors.
3. Palatal index: The ratio of the length of the palate to its breadth multiplied by 100. This is also called as palatomaxillary index

**Formula = palatomaxillary length/ palatomaxillary width\*100**

These are the parameters taken for the study.

In the endeavor to understand their forensic significance

- A study has been made to correlate the rugae patterns with the palatal dimensions (width, length) and palatal arch.
- This study aims to compare the possible relationships between the total number of rugae patterns and palatal measurements
- Rugae patterns are studied for observations and

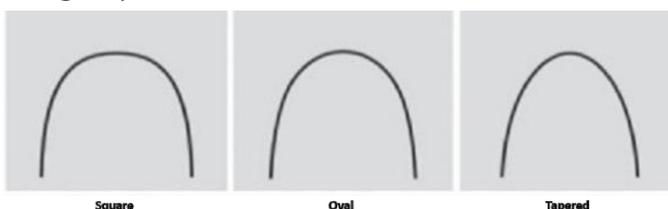


Fig 1: Arch Shapes

matched with the intermolar width, inter canine width, and arch length in the maxillary part

- To evaluate the gender differences in the shape of PR, palatal arch, and palatal dimensions
- Identify the most predominantly occurring type of afore-mentioned characteristics in each sex.
- To understand the distinctive rugae patterns of study populations.

The sole objective of this study is to "predict sex from examination of all above parameters and attempt to show if there lies any association between rugae and maxillary features to identify gender" to establish identity.

### Materials & Methods

This study was conducted during the period of December 2022-April 2023 and samples were collected from the students of Annai Fathima College of Arts and Sciences, Madurai.

Participants-

**Inclusion criteria:** Patients who are devoid of congenital abnormalities, inflammation, trauma, and orthodontic treatment are included (to ensure the positive appearance of fully developed dental arches).

**Exclusion criteria:** Cleft palate, bony and soft tissue protuberances, active lesions, trauma of palate, and patients with braces were excluded.

The patient was explained the procedure in simple terms. To prevent gagging due to the backward flow of the excess material into the throat the patient is made to sit upright. And the patient is advised to breathe through the nose and in case of gagging asked to look downwards. We practiced the placement of the empty tray into the patient's mouth. The operator's position was at 11 O'clock, and the patient was made to sit in such a way that the occlusal plane was positioned parallel to the floor. A wad or glob of material is placed in the palatal crypt of the patient just behind the incisors, to get rid of the trapped air and to ensure the proper duplication of palatal tissue. To retract the cheek, thumb, and index finger of the free hand is employed. The inserted tray is straightened so that it is in line with the patient's mid-face and light pressure is applied upwards as late as the light remonstrance or objection is detected.

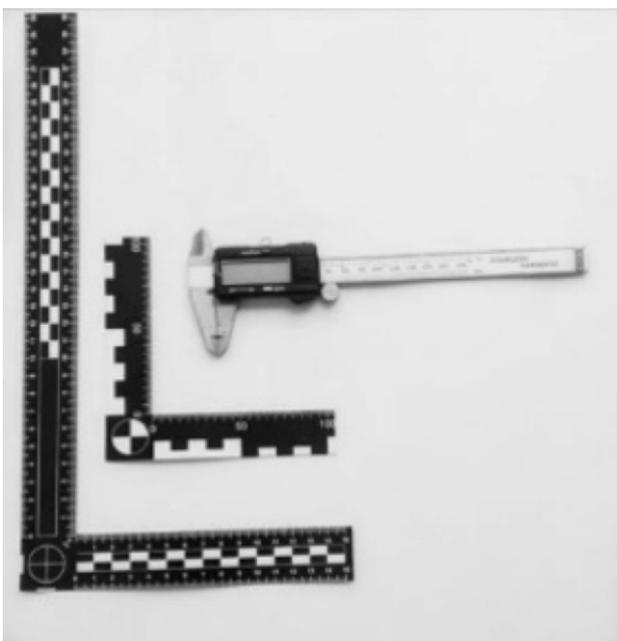
## Method of Identification

The sample obtained is evaluated by utilizing the upcoming procedures:

Materials required for examination of sample-

- Illuminating light
- Metallic wire
- Metallic scale
- 0.5 black graphite pencil
- ABFO scale (American Board of Forensic Odontologists- This scale was proposed by the ABFO board to take photographs of bite mark evidence to correlate with the human mouth. In this research, the ABFO scale is used to measure the dimensions of the maxilla.
- Digital vernier caliper (it is a precision instrument employed to take accurate measurements (Fig 2). Specifications-range:0-6 inch/0-150 mm; resolution:0.0005 in/0.01mm; accuracy: +/- 0.001 in /0.02 mm; measuring speed:1m/s)
- A study titled "A simple working type Integrated Rugoscopy Chart Proposed for Analysis and recording rugae pattern"<sup>15</sup> was conducted by Aman Chowdhry to record and analyze rugae types about their morphological features. The scientific structure of IRC proposed by Aman Chowdhry is given below, the same is used in this research to observe characters of rugae.

All the above parameters are measured utilizing a digital



**Fig 2:** ABFO Scale and Vernier caliper Recording data (rugae types)

vernier caliper and metallic scale, these measurements are noted down to compare the same with the PR and arch type. These features of maxillary impressions are correlated with one another to predict gender.

## Statistical analysis

All statistical evaluation was done using IBM SPSS (statistical package for the social sciences) Statistics (version 29.0.0.0 [241]). To correlate means and relationship between attributes (rugae parameters and arch type) two-sample t-tests were used. The total number of the different rugae patterns was counted and analyzed, the percentages of each were recorded, and bar charts and pie charts were used to describe the distribution of the various patterns within the samples studied. Associations between the distributions(direction) of the different rugae shape about sex were correlated using chi-square analysis. ( $P \leq 0.01$  is considered as being statistically sig.) The correlation between means and proportions of arch parameters are calculated by paired sample t-test (95% Confidence Interval of the Difference).

## Observations and Results

All parameters of rugae and maxillary features are correlated for highlighting the variations of attributes in male and female samples and found that:

**Forensic reliability:** Rugae-It was ascertained that no two rugae were similar, i.e., unique to every individual hence can be used as a reliable source for personal identification. Maxillary features-These attributes can be used for sex identification since their measurements vary in males and females. This gives rise to different arch types in both sexes.

## Research findings-

- Number-Male population has a greater number of rugae than females.
- Shape-Straight rugae was the most occurring rugae in primary rugae. The least occurring rugae types are circular forms (Fig 3).
- Length-Primary rugae were found to be large in number in both males and females followed by secondary. Fragmentary rugae were found to be more in females than males(Fig 4,5).
- Direction-Forward directed rugae are more in number than backward and perpendicularly directed rugae,in

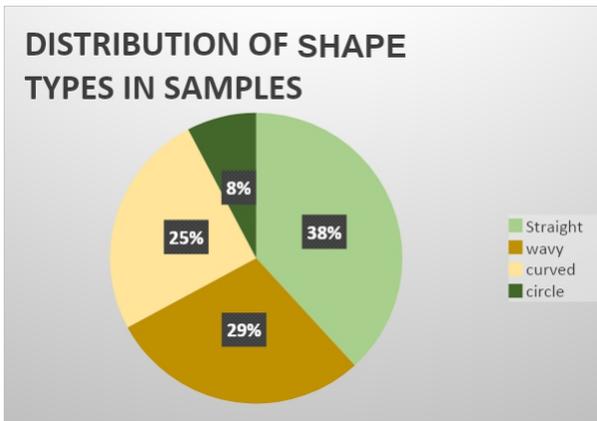


Fig 3: Graph showing the distribution of shape type

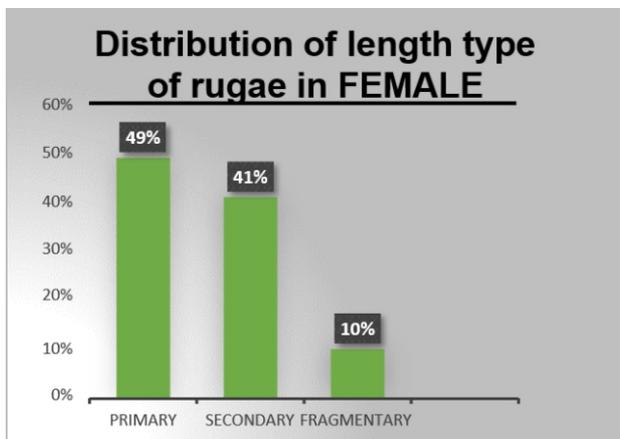


Fig 4: Graph Showing distribution of length of rugae in female

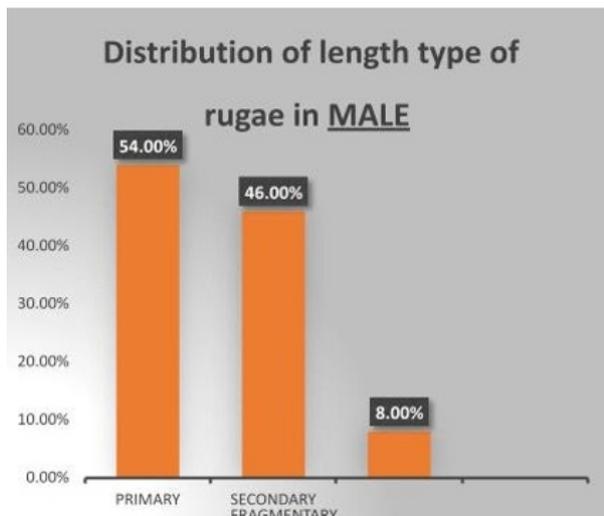


Table 1: Relationship between gender and direction of rugae

Direction * Gender Crosstabulation				
Count		Gender		Total
		FEMALE	MALE	
Direction	backward	14	14	28
	forward	24	25	47
	perpendicular	12	11	25
Total		50	50	100

both sexes (Table 1).

Unification-In most rugae unification was not found, yet in females it was more in number (both convergence and divergence) than in males (Fig 6).

- Arch width-Values obtained expressed that males have higher values than female subjects.
- Arch width and arch length-Values obtained expressed that males have higher values than female subjects.
- Arch type -Maxillary arch type was estimated and it was ascertained that all three arch types were distributed in males and females yet tapered arch type was the most prevailing in females whereas in males square arch type was the recurring type. The occurrence of an oval type of arch varied slightly in both sexes (Table 2).

Discussion

The present study evaluated the various shapes of rugae, level of predominance, combination pattern, total number of rugae, and length of rugae. Different rugae shapes were elucidated with varying degrees of predominance. Distribution of length types (primary, secondary, fragmentary) of rugae in the total population of study i.e. primary 49% (384), secondary-40% (303), fragmentary-11% (80). It shows that primary rugae are present more in number and then followed by secondary rugae and fragmentary in both females and males. Fragmentary rugae occur at a higher rate in females when compared with the male population. In this study, the primary rugae were more in number compared to secondary and fragmentary rugae. These results were in agreement with the study results of Ahmed and Hamid<sup>8</sup> who found out that primary rugae were more recurring followed by secondary and evaluation of rugae length expressed that they were primary rugae. The males in sample populations had more primary rugae than females and this observation corresponds with that made

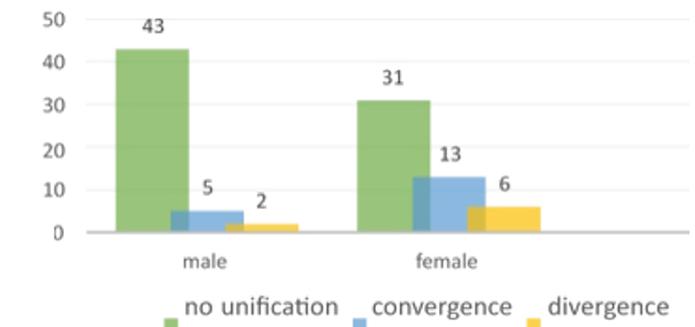


Fig 6: Unification of Rugae



**Table 2:** Paired Sample Statistics. These are the observations inferred from the sample (maxillary casts) analysis.

		Paired Samples Statistics			
		Mean	N	Std. Deviation	Std. Error Mean
<b>Pair 1</b>	Arch width female	46.6326	50	.26946	.03811
	Arch width Male	48.0680	50	.19981	.02826
<b>Pair 2</b>	Arch length female	47.3954	50	5.39414	.76285
	Arch length Male	47.0082	50	1.91707	.27111
<b>Pair 3</b>	Palatal index female	50.7718	50	6.94483	.98215
	Palatal arch Male	47.7394	50	7.17209	1.01429

by Shetty et al. In this study, males had a greater number of rugae when compared to females. And also the study conducted by Kumar T<sup>11</sup> reveals the same i.e., primary and secondary rugae were found to be larger in number in males when compared to females. The result of the present study was in agreement with a study conducted by Indira et al., who found that number of rugae was a little higher in males. Bing et al.<sup>9</sup> also found that the number of rugae was higher in males. Palatinas et al<sup>10</sup> and Bing et al. also found in their research that the number of rugae was higher in males; whereas Verma et al. and Manjunath et al. found that there were more rugae in females. Kapali et al in their study did not reveal any significant differences in the number of primary rugae among males and females. Yet, the present study expressed a significant difference in the number of rugae between males and females. Straight shape is predominant in both males and females yet more number of rugae is observed for all rugae shapes in male subjects. This proves that the male population has a higher number of rugae than the female population. Elrewieny N M et al.,<sup>14</sup> revealed in their study that the primary PR was more than the secondary PR which remains in the present study.

Regarding shape primary rugae are straight in shape, yet Ohtani et al. Indira et al. Sharma et al. show curved patterns are higher, while Manjunath et al. in their studies show wavy patterns are higher. It can be concluded that certain rugae shapes are specific to distinct populations and may have better utility in other population differentiation. The study conducted by Faheem, S et al.,<sup>13</sup> concludes that the predominant shape was found to be sinuous (AKA-wavy) yet the present study reveals that the recurring type was straight in both genders. Elrewieny N M et al.,<sup>14</sup> revealed in their study that the wavy rugae were the most predominant type followed by the straight rugae, yet the present study shows that the straight rugae were the most predominant

type followed by the wavy rugae.

Unification (forked rugae) was found in primary rugae yet in other types like secondary and fragmentary it was not found. Regarding unification, females have higher convergence and divergence when compared to males while Manjunath et al. Sharma et al. Azab et al. and Rajan et al. did not identify any significant variations for unification in both genders. The study results, a study conducted by Chopra et al. in 2013 expressed the presence of a large number of divergent rugae in females when compared to males. About direction, forward-oriented rugae are large in number and distribution in both sexes followed by backward and perpendicular.

Direction (forward, backward, perpendicular) wise distribution of rugae in males and females in which the study population possesses 50%-forward, 29%-backward, 21%-perpendicular. It explains that the forward pattern remains to be more in number when compared to backward and perpendicular (forward > backward > perpendicular). The right and left distribution of rugae pattern revealed males and females had more rugae on the right as compared to the left and this contradicts Kapali et al., Paliwal et al., and Madhan Kumar et al, (did not find a great variation between the left and right palates in discrete population). The present study reveals that negative angulation was found to be almost equal in number for both genders which remains in contradiction with the study conducted by Gupta et al.,<sup>12</sup> which says that the male population possesses a larger number of backward rugae (negative angulation) when compared to females.

These are the aspects in which the present study is in accordance and contradiction with other related studies in the discipline of forensic odontology<sup>12,14</sup>.



## Conclusion

There are many studies on rugae patterns and palatal arch dimensions for sex determination as individual parameters, but studies combining them are scanty. This study was done to assess whether these two parameters can be used separately or in combination with each other to predict sex. Odontological exhibits are an admissible and reliable source for identifying corpses to predict gender with the above-mentioned features yet personal identification can be performed only if ante-mortem data are available. It can be safely concluded that the palatal rugae pattern and maxillary palatal dimensions can be used as an additional technique in differentiating sex between human population groups. From this study, it was found that maxillary palatal dimensions and palatal rugae pattern in conjunction can be used as a tool in gender determination.

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