Forensic Identification through Palatal Rugae: A Comparative Study of Palatal Rugae Patterns in the Negroid Population

Manish Gupta[1], Anugya Agarwal[1]
[1]Department of Forensic Science, Galgotias University, Greater Noida

Corresponding Author
Dr. Anugya Agarwal
Department of Forensic Science,
Galgotias University, Greater Noida
Email: anugya.agrawal@galgotiasuniversity.edu.in

Abstract:
Palatal rugae, also referred to as plicae palatine transverse or rugae palatine, are transverse ridges composed of connective tissue located on the front surface of the palate. Once developed, their configuration remains consistent. The objectives of this study are to is to determine the rugae patterns of Negroids and find any gender differences in them. The study was made up of 50 participants, comprising of 25 males and 25 females Negroids between the ages of 18 and 30. A permanent hydrocolloid (alginate) impression of the maxillary arch was made and a study cast of the alginate impression was created using dental stone. The rugae patterns were classified using the Thomas and Kotze's classification (1983). Statistical evaluation was done using unpaired t-test. $p<0.05$ and $p<0.01$ were considered statistically significant. There was a statistically significant difference ($P<0.05$) in the females' converging pattern on the hard palate's entire surface. In contrast, a statistically significant difference was observed in the females' diverging pattern on the right side of the palate ($P<0.05$) and a highly significant difference was observed in the converging pattern of females on the left side of the palate ($P<0.01$). The personal, distinctive, and useful palatal rugae patterns aid in the gender determination of humans. Additional research is necessary to fully understand the patterns of palatal rugae patterns of Negroids utilizing larger sample size.
Keywords: Negroid; Rugae pattern; Thomas and Kotze's classification; Maxillary arch etc.
How to cite this article: Gupta M, Agarwal A. Forensic Identification through Palatal Rugae: A Comparative Study of Palatal Rugae Patterns in the Negroid Population. Int J Drug Deliv Technol. 2026;16(63s):352-358. DOI: 10.25258/ijddt.16.63s.37
Source of support: Nil.
Conflict of interest: None

Introduction:

The broad area of forensic science applies scientific methods and ideas to the study of criminal cases and legal matters. It includes a range of scientific fields to collect, examine, and interpret evidence from crime scenes, including toxicology, ballistics, biology, questioned document, physics, chemistry and psychology. Establishing facts or evidence that can be used in court to help resolve legal conflicts, such as those involving criminal investigations, civil lawsuits, and regulatory problems, is the main objective of forensic science. To analyze physical evidence, including blood, footprints, trace evidence (such as glass fragments, hair), digital data, and more, forensic scientists employ a broad range of specialized procedures and technology.

Since forensic science offers unbiased, scientific analysis to support law enforcement, legal practitioners, and the judiciary in their pursuit of justice, it plays a critical role in criminal justice systems across the globe. It is useful in identifying suspects, clearing innocent people, reconstructing crime scenes, figuring out the cause of death, assessing the veracity of documents, and offering expert testimony in court.

Forensic odontology is one of the many subfields of forensic science. The scope of forensic odontology includes identifying evidence such as teeth, jaws, bite marks, and dental traumas. Analyzing this dental evidence allows forensic odontologists to determine age, sex, and the identity of someone. For millennia, people have used examinations of their teeth and jaws to determine their identity. But in recent years, the complexity of the evidence required to identify human remains or suspected criminals that will subsequently be admitted in court has increased. Hence a need to come up with new techniques to identify individuals.

Some of the challenging cases we come across in forensic science is mass disaster cases such as plane

crash, tsunami, earthquake, train crash, terrorist attacks etc. Forensic odontology becomes particularly helpful in determining the identify of severed, disfigured, and extremely decomposed human remains. Determining the age, sex, ancestry, and other physical aspects of the body, such as height, weight, and individuality traits, is the main goal when dealing with mass disaster cases, or cases when body is completely disfigured. However, in such cases you may come across mixed skeletal remains, meaning the hand you find next to one body may not belong to that body. The physical nature of the evidence, which can include teeth, dismembered body parts, hair etc, dictates the appropriate course of action. (Thompson and Black 2007). Thus, using conventional methods to identify a body may not be possible in these cases.

Palatal rugae, also referred to as plicae palatinaetransversae or rugae palatine, are transverse ridges composed of connective tissue located on the front surface of the palate. These ridges extend across the maxillary bone and fan out diagonally from the incisive papilla, typically forming distinct, slanted ridges. (Hemanth et al. 2010). The third month of intrauterine development is when they first appear. (Venegas et al. 2009). Growth and development were regulated by epithelial mesenchymal interactions, where certain extracellular matrix chemicals articulate development in a spatiotemporal manner (Amasaki et al., 2003). In human embryos measuring 32 mm in crown rump length (CRL), the first rugae can be identified adjacent to the incisive papilla (Buchtová et al. 2003).Once developed, their configuration remains consistent, although alterations in their size can occur as a result of palate growth. (Jordanov 1971, Lang and Baumeister 1984) After reaching the age of ten, the lengths of the anterior rugae do not undergo any further increase. (Vanderli 1973).

In the human oral cavity, palatal rugae contribute to the digestive process and serve additional roles in chewing, speaking, swallowing, and facilitating milk consumption during infancy. (Thomas et al. 1987).

The study of palatal rugae is termed palatoscopy or palatal rugoscopy. Winslow was the first person to describe Palatal rugae in 1732. Then in 1889 Trobo Hermosa suggested the application of palatal rugae patterns for personal identification. Furthermore, Hermosa was the first person to come up with the name Palatal rugoscopy.Palatal rugae are beneficial in forensic science because buccal pad of fat, the lips, the cheeks, the tongue, and the teeth provide good protection for it in cases of fire and high-impact trauma hence it will remain unharmed and can be used as evidence. Palatal rugae also seldom alter shape with age or return following trauma or surgical treatments. (Rajendran, 2009) They are thought to be specific to each person and remain unaffected by chemicals, heat, illness, or trauma (Almeida et al.,1995). Thus, the distinctiveness of palatal rugae makes them useful for personal identification. However, factors such as intense finger sucking during infancy, continuous pressure from orthodontic treatments, and occurrences like trauma can potentially alter the pattern of rugae. (Lysell 1955). However, this doesn't mean it is not useful because the same is true for fingerprints, they may be altered if one experiences trauma however, they are still invaluable.

A study conducted by Shukla et al., (2011) showed that shape and orientation of the rugae pattern are independent of genetics, parents and children have different patterns. Furthermore, even in the case of twins, the palatal rugae are similar but not identical (Simon,2023). Thus, they are an advantageous tool for personal identification.

Rugoscopy can only be an appropriate forensic identification technique when ante-mortem data, such as dental casts, tracings, or digitalized rugae patterns, is available for comparison (Nayak et al., 2007). When employed inadvertently to aid in identification, other cast features like edentulous ridge morphology, teeth, vestibular depth, muscle attachments, or some combination of these may affect the outcome (Bansode and Kulkarni, 2009)

Research suggests that rugae analysis could be useful in racial profiling since it can reveal characteristics unique to particular racial groupings (Kapali et al., 1997). However, there are not as many studies on palatal rugae of Negroid populations as there are for other demographics, making the Negroid population and ignored population in this specific scientific research. Studying marginalized communities scientifically is important because it increases research variety. The generalizability and application of research findings are enhanced when various populations are included in scientific investigations. Additionally, it guarantees that whatever scientific procedures or instruments we employ are repeatable across all populations. It can also serve as a barometer to help us determine whether the techniques or tools we have created are targeted at a certain population rather than all populations.

For instance, certain formulas can be used to determine stature based on the index finger. Research can be done to establish a formula that applies to Negroids if a formula for calculating stature from the index finger was tested on a population of Negroids and the findings showed that the stature could not be reliably determined. As a result, this will increase scientific understanding because we now know that the existing formula can only be used to a specific

demographic. Thus, in order to further scientific understanding and achieve equity, it is imperative that studies of marginalised people be conducted. Consequently, the study's goal is to determine Negroid rugae patterns. Knowledge from this research will be useful in contributing to the data on how to profile Negroids using their palatal rugae.

According to studies done by Ibeachu, Didia and Arigbede (2014) given that palatal rugae are specific to each individual, they can be successfully used in human identification.Research done on specific populations indicate that, when used in conjunction with other techniques, rugae patterns can serve as an extra means of distinguishing between males and females (Saraf et al., 2011). Thus, perhaps the same can be true for Negroid population.

Thus, the purpose of this study is to compare and contrast the palatal rugae patterns of male and female Negroids in order to identify any gender differences in these patterns.

To be able to study rugae patterns we need a way to classify them. There are multiple methods used to categorize palatal rugae. The initial classification system was devised by Goria in 1911 and was basic in nature (Sanjaya et al.,2012). In this study the Thomas and Kotze (1983) method of classifying palatal rugae will be used.This categorization encompasses factors such as the shape, number, length and type of rugae pattern.

Materials and Methods:

Sampling;

Sample size consisted of 50 Negroid participants. Twenty-five male and twenty-five female subjects made up the study's fifty total participants. The subjects were between the ages of 18 and 30. This study did not include participants with congenital anomalies, a history of prior orthognathic surgery, bone and soft tissue protuberances, active lesions, deformity, or scarring. Prior to the commencement of the investigation, the patients provided their informed consent.

Impression taking and cast making;

A permanent hydrocolloid (alginate) impression of the maxillary arch was created. The alginate paste was made by mixing drinking water and the alginate powder per the manufacturer's instructions. The alginate powder used was by company named Piscium. The alginate paste was loaded into plastic maxillary impression trays. With the subject sitting in an upright position, the tray was inserted into the mouth of the subject and placed on the maxillary arch of the subject for a minute and then removed. The same operator took the impressions in order to correct any technique faults that occurred internally.

A study cast was then created by mixing dental stone with water. The mixture is poured onto the impression. and given time to cure overnight. Once the stone is set, the alginate impression is dislodged from the stone by tapping the sides of the impression tray and pulling the stone away.

Classification of palatal rugae;

A magnifying glass was used to inspect the cast thoroughly and look for the rugae patterns on the impressions. The impression was divided into two (left and right side) using the mid palatine raphe. The rugae patterns were outlined using a graphite pencil to make them stand out. The rugae patterns observed were classified in accordance with Thomas and Kotze's classification (1983). The rugae patterns are classified into 3 main categories on the basis of shape, length and unification.

By assessing the length of all rugae, Thomas and Kotze, (1983), have delineated three distinct categories.

1. Primary rugae; rugae patterns that have the length of (5-10 mm)
2. Secondary rugae; rugae patterns that have the length of (3-5 mm)
3. Fragmentary rugae; rugae patterns that have the length of (less than 3 mm).

Consequently, a digital vernier calliper was used to measure the length of each and every rugae pattern. Subsequently, the rugae was classified as primary, secondary, or fragmentary depending on their length. In addition, the frequency of rugae was determined by counting and recording the number in each category (primary, secondary, and fragmentary).

In this classification, individual rugae shapes are categorized into four primary types. The shapes are as follows;

1. Wavy – Serpentile
2. Curvy – crescent shape, slightly curved
3. Straight – Runs directly from start to termination
4. Circular – Definite, continuous ring formation, diameter from origin to termination is considered

As a result, the shape of each rugae that was seen was determined using these four categories. Every shape's frequency was observed. It was also observed how common each shape was on the left and right sides of the mid palatine raphe.

Another category of the classification given by Thomas and Kotze, (1983), is unification. When two rugae join at their terminal or origin, unification is

seen. Consequently, two groups of rugae were established based on their unification.

1. Diverging: When two rugae split out right away from the midline despite sharing the same origin.
2. Converging: Rugae whose lateral sections unite despite their distinct origins from the midline.

In light of this, any unification rugae that were found were classified as either converging or diverging according to their characteristics. Additionally, the number of times each was observed was counted.
It was recorded how frequently the left and right sides displayed the diverging pattern. The converging pattern underwent the same procedure. Lastly a count of all rugae in each sample was conducted.

In order to compare the two genders, the acquired data was separated into male and female categories. For both men and women, the total number of primary, secondary, and fragmentary rugae was recorded. For both men and women, the total number of rugae with curved, wavy, round, straight, converging, and diverging shapes was counted and recorded. The hard palate was split in half, and the total number of each rugae shape, as well as the left and right unification patterns, were tallied and recorded for each gender, respectively.

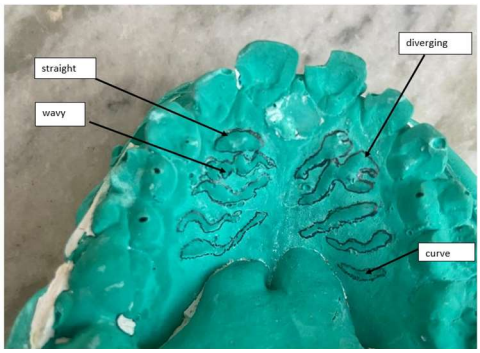


Figure 1 dental cast with outlined rugae patterns

Statistical analysis;

The results were statistically analysed. Statistical evaluation was done using unpaired t-test. $p<0.05$ and $p<0.01$ were considered statistically significant.Results:

1. **Identification of average number of rugae in male and female of Negroid population**

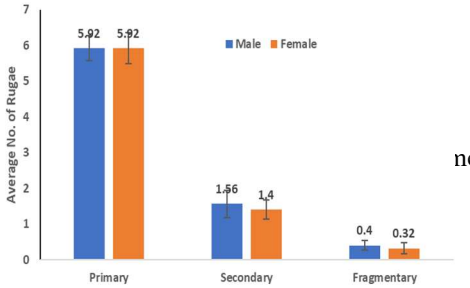
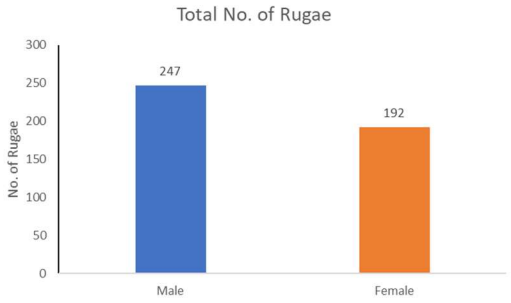


Figure 2: Total number of rugae in Males and Females

Figure 2 is a graph showing the total number of palatal rugae found in the female and male samples. 247 rugae were found in men and 192 were found in females. Average number of rugae was found approximately similar in the male and female of



negroid population.

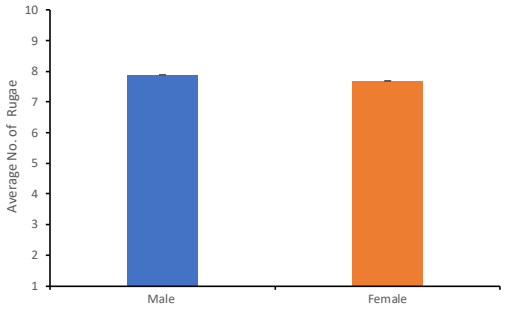


Figure 3: Average number of rugae in Male and Females

2. **Distribution of primary, secondary and fragmentary rugae of the negroid population:**
Figure no. 4 shows the detailed distribution of palatal rugae characteristics among males and females with their descriptive statistics and tests of significance. There were no significant differences either in the total number of rugae of primary, secondary and fragmentary rugae between males and females.

Figure 4: Average number of primary secondary and fragmentary rugae in Males and Females

3. Identification of the number of rugae on the basis of shape in male and female:

In the present study, there were no significant difference found in the wavy, circle, straight, curve, and diverging in the male as compared to female. However, average no of converging was found to significant in female as compared to male in the negroid population.

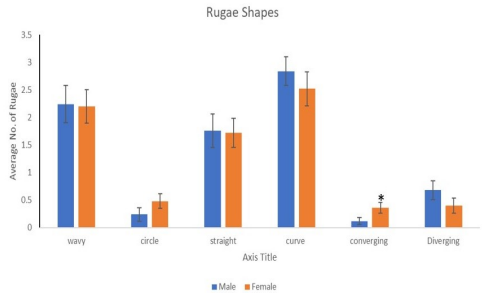


Figure 5: Identification of overall type of rugae shape in Males and Females

4. Identification of number of rugae on the basis of shape in the right- and left-hand side of maxilla

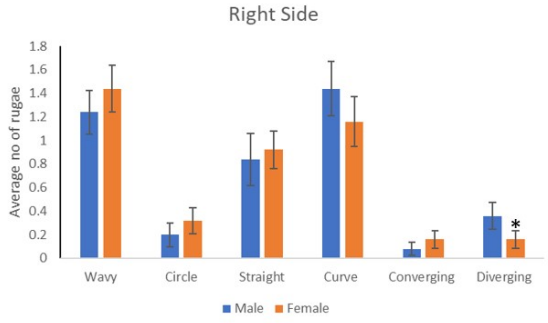


Figure 6: Identification of overall type of rugae shape on right side of mid palatine raphe in Male and Female

Figure 6 is a graph showing the average number of wavy, circle, straight, curve, converging, diverging rugae shapes on the right side of the mid palatine raphe of males and females.

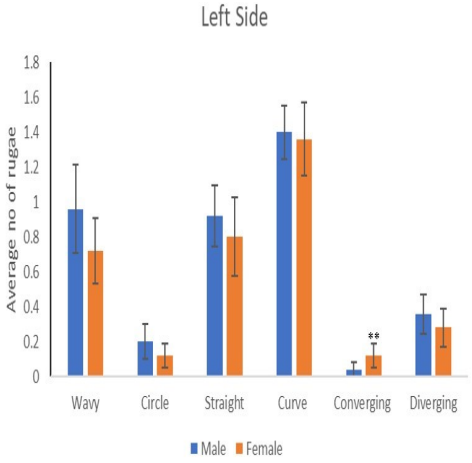


Figure 7: Identification of overall type of rugae shape on left side of mid palatine raphe in Males and Females

Figure 7 is a graph showing the average number of wavy, circle, straight, curve, converging, diverging rugae shapes in males and females on the left side of their mi palatine raphe.

Discussion:

Similar amounts of rugae were found in both men and women consequently so were the average number of rugae observed in both genders. Thus, males and females cannot be identified on the basis of their rugae number.

The predominant rugae length in both genders was primary rugae then followed by secondary rugae and then fragmentary rugae. Both genders also had the comparable amounts of average number of primary rugae, secondary rugae and fragmentary rugae. In both genders the primary rugae was very prominent, the average number of primary rugae was over 3 times that of the secondary rugae which was the second most prominent rugae. The average number of primary rugae were over 10 times more than the fragmentary rugae. This shows just how more dominant the primary rugae was in both genders as compared to the secondary and fragmentary rugae. So essentially Negroidsposses a lot of primary rugae.

The most prominent rugae shape in men was the curve, followed by wavy, straight, diverging, circle and converging. In women the most incident rugae shape was the curve followed by wavy, straight, circle, diverging and converging. In both males and

females, we cand see that the first three most incident rugae shapes are the same. Furthermore, the least incident rugae shape in both genders is the converging. It was also found that men have a greater number of average numbers of curve, wavy straight and diverging shapes than women. However, this difference was not statistically significant. In fact, the difference is not that great. E.g. if you look at figure 4 you can see that both men and women have similar average number of wavy patterns even though men do have more. However, there was a statistically significant difference in the converging pattern of females ($P<0.05$).

On examining the shapes of the rugae patterns on the right side of the mid line palatine rugae the men still had the same order of most incident rugae shapes like they did in the overall palate. However, in women the most incident rugae shape observed was the wavy not the curved like was observed. On the right side of the palate, women were also found to have more average number of rugae shapes than men however, for most of these the difference was not statistically significant. Although, there was a statistically significant difference in the diverging pattern of females ($P<0.05$).

Inspection of the left side of the mid line palatal raphe revealed that in both male and women the order of incidence of rugae shapes was the same as the order observed when examining the average incidence of rugae shapes in the whole palate. The most dominant rugae shape was the curve and the least dominant was the converging. Furthermore, when comparing the average number of rugaes for each shape between the genders men had more average number of rugae. E.g. when comparing the average number of wavy rugae shapes in men and women, men had a higher number of average number of rugae shape. This trend can be seen in the circle, straight, curve and diverging rugae shapes. Nonetheless, there was a highly statistically significant difference in the converging pattern of women ($P<0.01$).

Conclusion:

Palatal Rugae patterns are useful in forensic science because they are considered unique and can be used for identification. They are especially useful in mass disaster victim identification because they can withstand trauma and still remain unchanged. Many studies have been done on palatal rugae patterns of individuals however, few have focused on the rugae patterns of Negroids hence the need for this study.

This study's primary goal was to examine the characteristics of both male and female Negroid palatal rugae and ascertain whether or not these characteristics could be utilized to establish an individual's sex. Both males and females displayed palatal rugae that were unique, proving the contention that palatal rugae is individualistic and useful for personal identification.

Moreover, both sexes displayed every characteristic listed by Thomas and Kotze. Both genders possessed all of the rugae shapes, lengths, and unification patterns reported by Thomas and Kotze. As a result, demonstrating that Negroids can be identified using their rugae patterns.

It is safe to conclude that primary rugae are more numerous in both males and females and fragmentary rugae are less numerous based on the length of the palatal rugae. Rugae have a higher number of curve shapes than converging patterns, with the former being more common and the latter the least common in both male and female individuals.

When it comes to the morphology of the palatal rugae in the unification pattern, sexual dimorphism in females was also determined to be statistically significant. In particular, there was a statistically significant difference ($P<0.05$) in the females' converging pattern on the hard palate's entire surface. In contrast, a statistically significant difference was observed in the females' diverging pattern on the right side of the palate ($P<0.05$) and a highly significant difference was observed in the converging pattern on the left side of the palate ($P<0.01$) when the hard palate was divided into two from the mid line palatal raphe.

In conclusion, the study discovered the rugae patterns of Negroids as well as the differences and similarities between the patterns on male and female rugae. The study's findings support the possibility of sexual dimorphism on the basis of palatal rugae. Perhaps more study with a larger sample size could be conducted in the future to confirm these findings. Palatrugae patterns of Negroids can be used in future studies to differentiate them from other races.

References

1. Almeida, M.A., Phillips, C., Kula, K. and Tulloch, C., 1995. Stability of the palatal rugae as landmarks for analysis of dental casts. *The Angle Orthodontist*, *65*(1), pp.43-48.
2. Amasaki, H., Ogawa, M., Nagasao, J., Mutoh, K.I., Ichihara, N., Asari, M. and Shiota, K., 2003. Distributional changes of BrdU, PCNA, E2F1 and PAL31 molecules in developing murine palatal rugae. *Annals of Anatomy-AnatomischerAnzeiger*, *185*(6), pp.517-523.

3. Bansode, S. and Kulkarni, M., 2009. Importance of palatal rugae in individual identification. *Journal of Forensic Dental Sciences*, pp.77-81.
4. BUCHTOVA, M., 2003. The development of palatal rugae in the European pine vole, Microtus subterraneus (Arvicolidae, Rodentia). *Folia Zoo*, *52*, pp.127-136.
5. Hemanth, M., Vidya, M., Shetty, N. and Karkera, B.V., 2010. Identification of individuals using palatal rugae: Computerized method. *Journal of forensic dental sciences*, *2*(2), p.86.
6. Jordanov, J.A., 1971. Growth of the hard palate in man: Anthropological characteristics. *Z MorpholAnthropol*, *63*, pp.230-237.
7. Kapali, S., Townsend, G., Richards, L. and Parish, T., 1997. Palatal rugae patterns in Australian Aborigines and Caucasians. *Australian dental journal*, *42*(2), pp.129-133.
8. Lang, J. and Baumeister, R., 1984. Postnatal development of the width and height of the palate and the palate foramina. *AnatomischerAnzeiger*, *155*(1-5), pp.151-167.
9. Lysell, L., 1955. Plicae palatinaetransversae and papilla incisiva in man; a morphologic and genetic study. *Actaodontologicascandinavica*, *13*(Suppl. 18), pp.5-137.
10. Nayak, P., Acharya, A.B., Padmini, A.T. and Kaveri, H., 2007. Differences in the palatal rugae shape in two populations of India. *Archives of Oral biology*, *52*(10), pp.977-982.
11. Rajendran, R., 2009. *Shafer's textbook of oral pathology*. Elsevier India.
12. Saraf, A., Bedia, S., Indurkar, A., Degwekar, S. and Bhowate, R., 2011. Rugae patterns as an adjunct to sex differentiation in forensic identification. *The Journal of forensic odonto-stomatology*, *29*(1), p.14.
13. Shukla, D., Chowdhry, A., Bablani, D., Jain, P. and Thapar, R., 2011. Establishing the reliability of palatal rugae pattern in individual identification (following orthodontic treatment). *The Journal of forensic odonto-stomatology*, *29*(1), p.20.
14. Simon, B.B., 2023. *Forensic identification of twin siblings and sex by digital palatal morphology* (Doctoral dissertation).
15. Thomas, C.J. and Kotze, T.J., 1983. The palatal ruga pattern: A new classification. *The Journal of the Dental Association of South Africa= Die Tydskrif van die TandheelkundigeVereniging van Suid-Afrika*, *38*(3), pp.153-157.
16. Thomas, C.J., Kotze, T.J.V.W. and Van der Merwe, C.A., 1987. An improved statistical method for the racial classification of man by means of palatal rugae. *Archives of oral biology*, *32*(4), pp.315-317.
17. Thompson, T. and Black, S. eds., 2006. *Forensic human identification: an introduction*. CRC press.
18. VANDERLI. FP, 1973, January. Dimensional and Positional Changes in Palatal Rugae. In *JOURNAL OF DENTAL RESEARCH* (Vol. 52, p. 281). 1619 DUKE ST, ALEXANDRIA, VA 22314: AMER ASSOC DENTAL RESEARCH.
19. Venegas, V.H., Valenzuela, J.S.P., López, M.C. and Galdames I.C.S.,2009. Palatal rugae: systematic analysis of its shape and dimensions for use in human identification. International Journal of Morphology. *27*(3), pp.819-825.