*Original Article*

# Palatal Rugae As an Alternative Method in Forensic Identification

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***Background***: Common forensic identification methods are dental evidence, fingerprint, and DNA. Although DNA is the most accurate method of them all, it remains unpopular due to its high cost and inaccessibility in natural disasters causing many casualties. Consequently, an alternative method is needed. Palatal rugae is a unique, stable, and resistant morphological landmark that has the potential to be an alternative method of forensic identification.

***Objective***: To examine the similarity of palatal rugae in the Minangkabau ethnic family relationship.

***Materials and Methods***: Cross-sectional study of 27 families consisting of father, mother, son, and daughter. The sample was taken randomly. Palatal rugae was extracted from alginate printing and yielded a study model for analysis. Fingerprints were printed onto white papers after they were all dyed blue. IBM SPSS 17 was used for statistical analysis with multiple regression tests.

***Results***: The results showed similarity of palatal rugae based on family relationship. Circular rugae of the son had similarities with that of the father ($p<0.05$), while that of the daughter was derived from the mother. Wavy rugae was derived from both parents ($p<0.05$). The right index fingers of both the son and the daughter were similar with that of their mother, whereas their left middle fingers were derived from their father ($p<0.05$).

***Conclusion***: The similarities of palatal rugae and fingerprints are influenced by genetic factors. Palatal rugae and fingerprints are useful identification methods in forensic science.

***Keywords***: Palatal rugae, Minangkabau family lineage, Fingerprints, Forensic identification

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The Republic of Indonesia, an archipelagic located at the confluence of three giant tectonic plates (Eurasia, India Australia, and the Pacific), is a Southeast Asia country with some territories in Oceania. Situated between the Indian and Pacific oceans, it is the world's largest island country, with more than thirteen thousand islands[1]. This geographical position causes Indonesia to be one of the countries prone to natural disasters, such as tsunamis, earthquakes, volcanoes, floods, and landslides, which cause many casualties. The deadly earthquake that struck Aceh, a town situated in Northern Sumatra in 2004, has caused many more earthquakes to the south of Sunda Strait[2]. West Sumatra, a province located in the western part of the island of Sumatra, has become the focus of the international community due to frequent natural disasters and the seismic gaps that potentially causes earthquakes of magnitude 8.8 to 8.9[2]. West Sumatra, a province located on Sumatra Island, is mainly inhabited by Minangkabau, the only one matrilineal ethnic group in Indonesia[3]. In this province, at least seven districts and cities are declared disaster-prone areas with 921,349 people living in the red zone[1]. The identification of disaster victims is a very challenging process in forensic science. Currently,

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fingerprints, dental evidence, and DNA are the well-known techniques in forensic identification. No two individuals have the same fingerprints. Fingerprint patterns are very useful in forensic identification for they are individual. The identification of teeth is very useful in natural disasters that cause many casualties. It a method that has 75% of accuracy[4]. Palatal rugae are anatomical wrinkles or folds called 'plica palatine', the irregular connective tissue located on the anterior third of the palate behind the incisive papilla. Due to it resistance to hostile conditions such as natural disasters and burns, palatal rugae can be used as a replacement for dental evidence and DNA, which are not only expensive but can easily destroy in the event of a natural disaster or burns. However, the unique pattern and structure of palatal rugae and fingerprints can be questioned as to whether they can determine the resemblance between relatives in one family. The aim of the present study was to examine the similarity of rugae palatina in Minangkabau family members.

## Materials and Methods

The present study was a cross-sectional study conducted between October 2017 and February 2018 on Minangkabau families at Luhak Nan tigo. Guguak, Sitta, and Tanjung Sub-districts represent Luhak 50 Kota, Tanjung Baru Sub-district representing Luhak Tanah Datar, and Baso Sub-district, Banuhampu and Tanjung Raya representing Luhak Agam. Twenty-seven families consisting of four family members namely father, mother, son, and daughter whose patterns of palatal rugae and fingerprints were observed. Ethical clearance has been conducted before the research with the 2015 080/KEP/FK ethical test number in September 2017. Upper jaws were first printed with irreversible hydrocolloid (alginate) (GC Aroma) then cast in dental stone type 3 mold. The maxillary mold was analyzed by two observers i.e. different dentists in single blind for more accurate measurements. The result of the measurement was tested by the Technical Error of Test Measurement (TEM) as much as 20 times the sample examination between the observers. The shape of palatal rugae was classified according to the Thomas Kotze classification method (Figure 1), the size of the palatal rugae was grouped by Sunita Kapali method.

### *Criteria*

Fingerprints of all the fingers on both hands were taken. The subject pressed one finger that had been stained with blue ink on a white paper. Fingerprints were grouped into eight patterns according to Henry's classification (1800), namely 1) whorl, 2) right loop, 3) left loop, 4) tented arch, 5) central pocket, 6) twin loop, 7) plain arch, and 8) accidental (Figure 2).

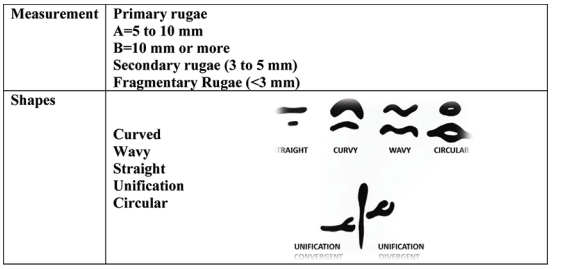


**Figure 1.** Shape of palatal rugae according to Thomas Kotze[5].

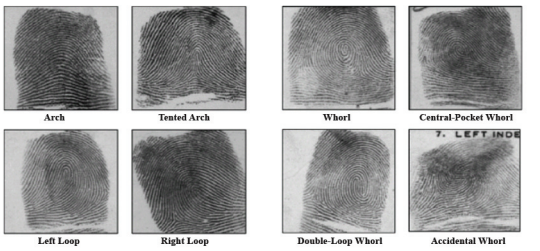


**Figure 2.** Fingerprint patterns according to Henry's classification[8].

Data was collected, decoded and analyzed statistically by using IBM SPSS Statistic 20 Software. Data was tested with multiple regression. The pair observation of fam-I (I-family) as ($x_{1i}$, $x_{2i}$, $y_{B,i}$, $y_{G,i}$) yielded two variable predictors namely $x_{1i}$ indicating the father's characteristic variable and $x_{2i}$ showing the mother's characteristic variable. While response $y_{B,i}$ indicates the characteristic variable of either the son (B: boy) or the daughter (G: girl). Thus, for each observed characteristic variable, it was obtained two multiple regression models defined as:

$$y_{B,i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \varepsilon_{B,i}$$

$$y_{G,i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \varepsilon_{G,i}$$

with normal identical independent distribution, (i.i.d) such as: $\varepsilon_{B,i} \sim N(0,\sigma_B^2)$ dan $\varepsilon_{G,i} \sim N(0,\sigma_G^2)$, $\beta_0$, $\beta_1$, and $\beta_2$, which are the regression coefficients.

There are 15 characteristic variables that are modeled and classified into three parts:

1. Rugae shape consisted of five characteristic variables, which are curved, straight, wavy, unification, and circular;

2. Right fingers consisted of five characteristic variables of the thumb, index finger, middle finger, ring finger, and the little finger; and

3. Left fingers made of five characteristic variables of the thumb, index finger, middle finger, ring finger, and the little finger.

## Results

Of the 27 families observed, 21 had with complete data for each characteristic variable, and of the 21 families, 13 had complete data of their fathers, mothers, and sons, and 11 families with complete data of fathers, mother, and daughter. The most dominant shape and size of palatal rugae in Minangkabau ethnic group is the circular pattern and the primary rugae (Table 1). The most dominant fingerprints are described in Table 2.

**Table 1.** The average distribution of the shape and size of the palatal rugae

| Palatal rugae | n | Mean±SD |
|---|---|---|
| Shape | | |
| Curved | 108 | 1.83±1.979 |
| Straight | 108 | 2.06±2.344 |
| Wavy | 108 | 2.82±2.351 |
| Unification | 108 | 0.81±0.929 |
| Circular | 108 | 0.24±0.578 |
| Size | | |
| Primary | 108 | 6.13±3.568 |
| Secondary | 108 | 1.12±1.477 |
| Fragmentary | 108 | 0.30±0.687 |

SD=standard deviation

The shape and size of the rugae did not show a significant resemblance between the children- father and mother. However, the present study showed specific patterns that could be inherited. Circular rugae of the son tended to be inherited from the father ($p=0.011$), while in the daughter, it was inherited from both the father and mother. Wavy rugae on the other hand, was handed down by the mother ($p<0.05$). Right index fingerprint shared a resemblance with the mother, while left ring fingerprint was more similar to that of the father ($p<0.05$). These are described in Table 3 and 4.

## Discussion

### *Understanding of palatal rugae*

Palatal rugae and fingerprints have morphological patterns that can be used in forensic identification. Palatal rugae is an asymmetrically extended anatomical bulge of the papillary insivum and the anterior part of the palatal media raphe[6]. 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[7]. Palatal rugae was first used in identification by Harrison Allen in 1889. Rugoscopy is the study of palatal rugae first discovered by Spanish researcher, named Trobo Hermosa[6]. Data on palatal rugae medical record was collected in South America because its level of accuracy in forensic identification surpasses that of fingerprints, especially in the event of a serious burn[8,9]. Palatal rugae is as strong and

**Table 2.** Fingerprints proportion

| Fingerprints | Whorl (%) | Right loop (%) | Left loop (%) | Tented arch (%) | Central pocket (%) | Twin loop (%) | Plain arch (%) |
|---|---|---|---|---|---|---|---|
| Right hand's fingerprints | | | | | | | |
| Thumb | 20.5 | 48.9 | 2.3 | 1.1 | 1.1 | 22.7 | 3.4 |
| Index finger | 21.8 | 40.2 | 0.0 | 9.2 | 6.9 | 18.4 | 3.4 |
| Middle finger | 14.6 | 64.0 | 0.0 | 5.6 | 3.4 | 11.2 | 1.1 |
| Ring finger | 40.4 | 36.0 | 0.0 | 2.2 | 10.1 | 11.2 | 0.0 |
| Little finger | 29.1 | 57.0 | 0.0 | 2.3 | 5.8 | 5.8 | 0.0 |
| Left hand's fingerprints | | | | | | | |
| Thumb | 17.4 | | 55.8 | 3.5 | 1.2 | 16.3 | 5.8 |
| Index finger | 24.4 | 1.2 | 37.2 | 11.6 | 4.7 | 18.6 | 2.3 |
| Middle finger | 19.8 | 2.3 | 57.0 | 3.5 | 1.2 | 12.8 | 3.5 |
| Ring finger | 36.9 | | 34.5 | 3.6 | 9.5 | 15.5 | |
| Little finger | 19.8 | | 67.9 | 2.5 | 8.6 | 1.2 | |

**Table 3.** A p-value for four types of hypotheses, related to the suitability of the regression model and the significance of the shape and size parameters of the palatal rugae

| | p-value | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Shapes rugae | | | | | Size of rugae | | |
| | Curved | Straight | Wavy | Unification | Circular | Primary | Secondary | Fragmented |
| Son (n=13) | | | | | | | | |
| $B_0$ | 0,148 | 0,038* | 0,083 | 0,177 | 0,635 | 0,007* | 0,144 | 0,168 |
| $B_1$ | 0,749 | 0,699 | 0,119 | 0,684 | 0,005* | 0,434 | 0,385 | 0,647 |
| $B_2$ | 0,370 | 0,356 | 0,466 | 0,903 | 0,326 | 0,197 | 0,194 | 0,538 |
| Model y | 0,612 | 0,577 | 0,270 | 0,916 | 0,011* | 0,216 | 0,176 | 0,761 |
| Daughter (n=10) | | | | | | | | |
| $B_0$ | 0,257 | 0,108 | 0,027* | 0,142 | 0,316 | 0,004* | 0,095 | 0,465 |
| $B_1$ | 0,516 | 0,303 | 0,093 | 0,456 | 0,018* | 0,289 | 0,480 | 0,797 |
| $B_2$ | 0,855 | 0,167 | 0,032* | 0,720 | 0,015* | 0,827 | 0,299 | 0,094 |
| Model y | 0,791 | 0,151 | 0,085 | 0,601 | 0,043* | 0,547 | 0,342 | 0,202 |

If the selected level of significance is ≥5%, then p-value is the small value implying that the null hypothesis (H0) is rejected, *p-value indicates the goodness of fit of the regression model at the characteristic variable indicated

**Table 4.** A p-value for four types of hypotheses, related to the suitability of the regression model and the significance of the parameters of the right hand and left hand fingerprint patterns

| | p-value | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Right fingers | | | | | Left fingers | | | | |
| | Thumb | Index finger | Middle finger | Ring finger | Little finger | Thumb | Index finger | Middle finger | Ring finger | Little finger |
| Son (n=13) | | | | | | | | | | |
| $B_0$ | 0.324 | 0.033* | 0.118 | 0.014* | 0.423 | 0.117 | 0.437 | 0.082 | 0.435 | 0.094 |
| $B_1$ | 0.627 | 0.348 | 0.169 | 0.894 | 0.938 | 0.877 | 0.628 | 0.927 | 0.953 | 0.945 |
| $B_2$ | 0.279 | 0.671 | 0.620 | 0.604 | 0.128 | 0.667 | 0.452 | 0.815 | 0.107 | 0.692 |
| Model y | 0.502 | 0.525 | 0.339 | 0.777 | 0.245 | 0.827 | 0.691 | 0.970 | 0.236 | 0.921 |
| Daughter (n=10) | | | | | | | | | | |
| $B_0$ | 0.568 | 0.060 | 0.026* | 0.319 | 0.007* | 0.059 | 0.422 | 0.018* | 0.007* | 0.001* |
| $B_1$ | 0.359 | 0.110 | 0.181 | 0.889 | 0.078 | 0.355 | 0.809 | 0.186 | 0.018* | 0.167 |
| $B_2$ | 0.306 | 0.030* | 0.942 | 0.573 | 0.157 | 0.888 | 0.732 | 0.511 | 0.510 | 0.291 |
| Model y | 0.482 | 0.021* | 0.382 | 0.672 | 0.141 | 0.620 | 0.873 | 0.357 | 0.049* | 0.148 |

If the selected level of significance is ≥5%, then the p-value is small values implying that the null hypothesis (H0) is rejected, *p-value indicates the goodness of fit of the regression model at the characteristic variable indicated

fixed as fingerprints and DNA since its quality does not deteriorate as the individual grows older[10]. Palatal rugae is the flesh located in the upper side of the mouth of an animal including humans which is protected by the lips, tongue and upper jaws. Because of its position, palatal is safe from decomposition and trauma. It is these unique characteristics of palatal rugae that make it so useful and valuable to forensic identification.

### *The role of palatal rugae in forensic identification*

Palatal rugae remains in good condition for at least 7 days after the death of an individual and has the ability to remain undamaged under hostile circumstances such as severe burn and trauma. It is this ability that makes palatal rugae very useful

in forensic identification[10]. Race, ethnicity, and geographical variations are also considered in identification, especially during natural disasters and anthropology[11]. The present research was conducted in three areas namely Luhak Agam, Luhak Tanah Datar, and Luhak 50 Kota, mainly home to the Minangkabau native people. To conclude, it is worth noting that like fingerprints, palatal rugae can be used to indicate kinship and resemblance between relatives. Male children inherit their circular rugae patterns from their father as indicated in our previous study which argues that circular rugae patterns of siblings resemble those of their parents (Kasuma et al, 2018[12]). The present result is also in the line of Pasiga and Hardianti who studied the Bugis ethnic group[13]. Palatal rugae patterns of male children are more identical to their father than their mother. Circular rugae patterns in daughters are inherited from both parents. Wavy patterns, on the other end, come from the mother. These findings are similar with the study[6] stating the relationship pattern of palatal rugae shows a positive correlation between the child and both parents. Wavy rugae pattern is more derived from the mother than from the father. The patterns of palatal rugae are handed down by parents. Genetic affects the formation of morphological signs in a way that prevents the patterns of palatal rugae from being common. Based on Mendel's principle of inheritance, parents' genes are passed on to their children. Inherited traits are noticed according to the dominant gene. Palatal rugae patterns are not only influenced by genes but also by the environment. Orientation of collagen fibers during embryogenesis and the variety of palatal rugae patterns are controlled by genes. Palatal rugae patterns begin shaping in the 3rd month of intrauterine and its growth is controlled by the interaction of epithelial and mesenchymal, whereby extracellular matrix molecules appear[12].

## Conclusion

The most dominant palatal rugae patterns in the Minangkabau people are wavy patterns. However, the shape and size of palatal ruegae is not significant regarding kinship relationship. Even so, circular patterns in the son are derived from the father. In daughter, circular rugae patterns are derived from the father and mother while the wavy rugae patterns are inherited from the mother. The characteristics of the mother are more similar to those of the daughter than those of the son. Identification with palatal rugae is as accurate as the use of fingerprint. Since the present study was conducted on 27 families, further study is needed on more samples for better conclusions. There are hereditary factors in both palatal rugae patterns and fingerprints. Palatal rugae can be a genetic marker in future identification. The authors hope that the present research can contribute to the forensic odontolysiy, especially on the Minangkabau and Deutro Melayu ethnic groups.

## What is already known on this topic?

Common forensic identification methods in Indonesia include DNA, fingerprint, and dental record.

## What this study adds?

After the introduction of palatal rugae identification, dentists in Padang, West Sumatera, are now able to take patients' palatal rugae patterns for personal dental record data. Therefore, this study adds that in addition to common identification methods such DNA, fingerprints, and dental records, palatal rugae can offer a cheaper and more reliable way to identify individual.


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## Conflicts of interest

The authors declare no conflict of interest.

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