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Research Article

Association of Palatal Rugae Patterns in The Maternal Lineage Between Biological Mothers and Daughters of The Minangkabau Ethnic Group in Padang City

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KEYWORDS

Palatal rugae, Maternal inheritance, Minangkabau ethnicity, Forensic odontology, Rugoscopy

ABSTRACT

Introduction: Palatal rugae are unique, anatomically stable ridges in the oral cavity that serve as reliable markers for forensic identification and genetic research. The Minangkabau ethnic group, known for its matrilineal kinship system, to provides a unique context to for exploring the hereditary transmission of such traits. This study aimed to examine the morphological similarities and differences in palatal rugae patterns between biological mothers and their daughters within the Minangkabau ethnic group in Padang City, Indonesia.

Material and Methods: An analytical cross-sectional design was employed involving 53 mother-daughter pairs of confirmed Minangkabau descent. Intraoral digital scans were used to record rugae patterns which were categorized by shape and size based on established classifications. Statistical analysis was conducted using the Mann-Whitney U test to assess intergenerational associations.

Results and Discussion: Primary and secondary rugae patterns showed strong morphological similarities between mothers and daughters, indicating heritability. Notably, the wave-shaped rugae pattern was significantly more prevalent in daughters ($p < 0.05$).

Conclusion: Palatal rugae patterns, particularly primary and secondary types, demonstrate maternal inheritance and have potential forensic relevance. The presence of unique ethnic-specific traits underscores the need for broader population-based classifications in forensic odontology and antropology

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INTRODUCTION

Indonesia is the world's largest archipelagic country, strategically located between the Indian and pacific ocean and flanked by the continents of Asia and Australia. Positioned along the equator. The country is situated at the convergence of three major tectonic plates—Eurasian, Indo-Australian, and Pacific—placing it within the Pacific Ring of Fire and making it highly vulnerable to natural disasters such as earthquakes, tsunamis, volcanic eruptions, and landslides. According to the World Risk Index, Indonesia ranks second in terms of disaster risk[1]. The Indonesian Disaster Risk Index (IRBI) 2020 categorizes West Sumatra Province as a high-risk area with a score of 150.24, highlighting its susceptibility to multiple natural hazards. Padang City, in particular, experienced a devastating earthquake with a magnitude of 7.6 on September 30, 2009, resulting in 1,117 fatalities, thousands of injuries, and massive displacement[2,3].

In the aftermath of such disasters, forensic identification plays a crucial role, particularly when victims are difficult to recognize owing to severe trauma or incomplete remains. Forensic odontology is one of the primary methods employed to aid identification, leveraging the unique characteristics of, teeth and oral tissues[4,5]. Secondary method, such as odontograms, cheiloscopy, bitemarks, dental impressions, photography, and rugoscopy, are also utilized used to enhance the identification process[4,6]. Rugoscopy, the study of palatal rugae patterns, was first introduced by Trobo Hermosa in 1932 and has been recognized as a valuable, affordable, and reliable forensic tool due to because of the uniqueness and durability of palatal rugae. Morphologically, palatal rugae—also known as plica palatinae transversae—are irregular ridges located on either side of the palatine raphe, beneath the incisive papilla. These structures are highly individualized and remain relatively stable throughout life, protected within the oral cavity by the surrounding teeth, lips, tongue, and buccal pads, providing resilience against trauma and fire[8,9].

Palatal rugae play significant roles in genetic studies, the stomatognathic system, prosthodontics, orthodontics, and forensic odontology. They aid in food manipulation, mastication, and contain gustatory and tactile receptors that contribute to the perception of taste and texture[9]. Palatal rugae begin to develop developing during the 12th to 14th weeks of prenatal life and maintain a consistent morphology after the age of 10, with minimal changes observed even after 24 years of age[10]. Their temporal stability and resistance to heat have led to their increasing use in forensic identification, alongside fingerprinting, bite mark analysis, lip print analysis, and DNA profiling, with rugoscopy providing a cost-effective and accessible alternative when DNA analysis proves is too expensive or time-consuming[11,13].

The hereditary nature of palatal rugae patterns has been highlighted in several studies, suggesting that they can serve as important indicators of familial lineage[9,16,18,20]. Research on the Osing ethnic group in Banyuwangi, East Java, found similarities in rugae patterns among individuals of the same ethnic group, demonstrating the potential of palatal rugae for lineage tracing[12]. Similarly, studies conducted in Sri Ganganagar, India, emphasized the individualistic and gender-specific characteristics of palatal rugae, reinforcing their utility in personal and demographic identification[13].

The Minangkabau people, one of the largest ethnic groups in Sumatra[14,15,21]. Furthermore, a study involving the Minangkabau ethnic group revealed significant familial similarities in palatal rugae patterns among fathers, mothers, sons, and daughters[17]. This study aimed to analyze the association between the palatal rugae patterns of biological mothers and their daughters among the Minangkabau ethnic group in Padang City, in order to explore possible maternal inheritance and generational variations in palatal rugae morphology within a matrilineal population. Morphological similarities and differences, the study seeks to provide valuable insights into the hereditary aspects of palatal rugae for identification purposes.

MATERIALS AND METHODS

This study employed an analytical observational design with a cross-sectional approach, allowing for the concurrent assessment of the dependent variable, the palatal rugae pattern. The independent variable was the

maternal-daughter relationship. The relationship within the Minangkabau ethnic group at a specific point in time is explored. A cross-sectional design was selected to efficiently identify the association between hereditary factors and the morphological characteristics of the palatal within a limited time frame.

The research was conducted in Padang City, West Sumatra, Indonesia, from June- July 2025. The study setting included public community areas and healthcare centers where participant recruitment and intraoral scanning procedures were performed in accordance with ethical guidelines.

The study population comprised biological mothers and their daughters from the Minangkabau ethnic group residing in Padang City. Inclusion criteria were: mothers and daughters of pure Minangkabau descent (minimum two generations above confirmed), complete eruption of permanent maxillary teeth (I, C, P1, P2, M1, and M2), and willingness to participate with signed informed consent. Exclusion criteria included: history of orthodontic treatment involving tooth extraction or palatal expansion, habitual thumb sucking, progressive periodontal disease (chronic or aggressive periodontitis), history of prosthodontic appliance use, or history of cleft palate surgery. The primary outcome was the pattern of palatal rugae, which was examined for potential hereditary similarities between the mother and daughter pairs. Age of participants was recorded to account for potential influences on rugae morphology. Although palatal rugae patterns are generally stable after maxillary growth completion, slight age-related variations may occur; therefore, comparisons between mothers and daughters were interpreted with consideration of these possible differences.

Palatal rugae patterns were recorded using digital intraoral scanning (Intraoral Scanner PioCreat™), ensuring high-resolution three-dimensional imaging of the palatal mucosa. Shape classification based on the Thomas and Kotze system, categorized into Curved, Wavy, Straight, Circular, and Unification patterns. Meanwhile, size classification based on the Kapali system, categorized as Primary (5–10 mm), Secondary (3–5 mm), and Fragmentary (<3 mm). Data acquisition and analysis adhered to standardized protocols to minimize examiner bias and ensure the reproducibility of the results.

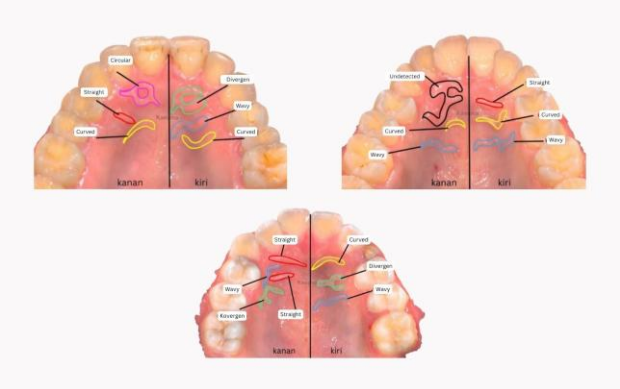

Figure 1. Rugae patterns were recorded using digital intraoral scanning (Intraoral Scanner PioCreat™)

The study included 106 participants, with a comparison of 53 biological mothers and daughters. The sample size was calculated based on the Lameshow formula, considering a 10% estimated dropout rate, ensuring sufficient statistical power to detect significant hereditary patterns in rugae characteristics.

All data were tabulated and analyzed using descriptive statistics to summarize ther rugae shapes and sizes in terms of frequencies and percentages. The Mann-whitney U test was employed to assess the association between the palatal rugae patterns of mothers and their daughters. A p-value < 0.05 was considered statistically significant, indicating a meaningful hereditary relationship in the morphology of palatal rugae between mother and daughter pairs.

The research protocol for this study was carefully reviewed and approved by the Research Ethics Committee of the Faculty of Medicine, Universitas Andalas (Approval No: 644/UN.16.2/KEP-FK/2025). The approval is valid for one year from the date of issuance. All participants provided informed consent before being included in the study. In the case of any Serious Adverse Events (SAEs), immediate reporting to the Research Ethics Committee was mandated. The committee ensured that the study protected the human rights and welfare of all subjects involved in accordance with national and international ethical standards.

RESULTS AND DISCUSSIONS

Palatal rugae, with their unique and stable morphological characteristics, have long been recognized as valuable anatomical landmarks in forensic identification, particularly in cases where traditional methods such as fingerprints or DNA analysis are compromised[16]. This section presents the results of a comparative analysis of rugae palatina patterns between biological mothers and daughters within the Minangkabau ethnic group, aiming to evaluate their potential heritability and forensic applicability. By analyzing the distribution, shape, and size of rugae based on established classification systems, this study explored the extent to which these patterns are conserved across generations.

Table 1. Age Distribution of Mothers and Daughters in the Minangkabau Ethnic Sample

Age	n	%
Mothers		
30-40	11	20.75
40-50	21	39.62
50-60	10	18.87
60-70	9	16.98
70-80	1	1.89
80-90	1	1.89
Total	53	100
Daughters		
10-20	33	62.26
20-30	14	26.42
30-40	2	3.77
40-50	4	7.55
Total	53	100

The age distribution of the mothers group was concentrated in the 40-50 year range (39.62%), , while the 70–80 and 80–90 year ranges represented the smallest proportions with equal percentages of 1.89%. In the daughters group, the highest proportion of respondents was in the 10–20 year age range (62.26%) and the lowest proportion was observed in the 30–40 year age range (3.77%) (Table 1).

Table 2. The distribution of palatine rugae patterns based on size in mothers and daughters of the Minangkabau ethnic group

Rugae Size Classification		n	%	Mean±SD
Mothers Group				
Primary	Right	157	52.7	2.96±1.176
	Left	141	47.3	2.66±1.224
Secondary	Right	66	58.4	1.25±1.175
	Left	47	41.6	0.89±0.87
Fragmenter	Right	45	54.9	0.85±1.026
	Left	38	46.3	0.72±1.082
Daughters Group				
Primary	Right	164	51.6	3.09±1.165
	Left	154	48.4	2.91±1.229
Secondary	Right	67	52.8	1.26±1.112
	Left	60	47.2	1.13±1.001
Fragmenter	Right	73	50.0	1.38±1.319
	Left	73	50.0	1.38±1.608

Based on Table 2, according to the Thomas and Kotze classification, the palatine rugae patterns in both groups were predominantly dominated by the right primary size. The mothers group had an average of 2.96 ± 1.176, while the biological child group had an average of 3.09 ± 1.165.

The analysis revealed no significant differences in the number and size of primary and secondary rugae between the maternal and filial groups ($p > 0.05$). This supports previous research, which emphasized that primary and secondary rugae are developmentally stable and largely immutable after formation, thus representing reliable traits for genetic and forensic identification[20]. Similarly, other studies have confirmed that these types of rugae are the most consistently inherited and least affected by environmental pressures[7].In contrast to this stability, the fragmentary rugae on the right side showed a statistically significant difference ($p = 0.019$), with daughters displaying a higher frequency. Similarly, wavy patterns exhibited highly significant differences on both sides (right: $p = 0.038$; left: $p = 0.005$). These results echo the findings of previous research, which noted that fragmentary rugae, due to their short, irregular nature, tend to be more developmentally sensitive to environmental conditions, including oral behaviors, orthodontic interventions, or craniofacial growth dynamics[23].

Table 3. The distribution of palatine rugae patterns based on shape in mothers and daughters of the Minangkabau ethnic group

Rugae Shape Classification		n	%	Mean±SD	Min	Max
Mothers Group						
Curve	Right	43	53.1	0,81±0.9	0	3
	Left	38	46.9	0,72±0968	0	4
Wave	Right	112	53.8	2,11±1,086	0	5
	Left	96	46.2	1,81±1,001	0	4
Straight	Right	65	57.0	1,23±1,086	0	5
	Left	49	43.0	0,92±0,895	0	3
Circular	Right	4	40.0	0,08±0,267	0	1

	Left	6	60.0	0,11±0,375	0	2
Convergent	Right	5	38.5	0.09±0.295	0	1
	Left	8	61.5	0,15±0,411	0	2
Divergen	Right	13	39.4	0,25±0,434	0	1
	Left	20	60.6	0,38±0,489	0	1
Daughters Group						
Curve	Right	39	50.0	0,74±0,812	0	2
	Left	39	50.0	0,74±0,836	0	4
Wave	Right	139	51.5	2,62±1,228	0	5
	Left	131	48.5	2,47±1,219	0	6
Straight	Right	55	56.7	1,04±0.919	0	4
	Left	42	43.3	0,79±1,007	0	4
Circular	Right	3	50.0	0,06±0233	0	1
	Left	3	50.0	0,06±0,233	0	1
Convergent	Right	5	45.5	0.09±2,295	0	1
	Left	6	54.5	0,11±0,32	0	1
Divergent	Right	15	39.5	0,28±0,495	0	2
	Left	23	60.5	0,43±0,572	0	2

According to the data presented in Table 3, the palatal rugae patterns based on the classification of Thomas and Kotze revealed that, within the mothers group, the most prominent rugae shape is was the right wave type, with a mean of 2.11 ± 1.086, where the minimum count was 0 and the maximum count was 5 rugae. In contrast, the daughters group predominantly exihibited the right straight type, with a mean of 1.04 ± 0.919, a minimum count of 0, and a maximum count of 4 rugae. The rarest rugae shape in the mothers group was the right circular type, with a total of 4 rugae, a mean of 0.08 ± 0.267, a minimum count of 0, and a maximum count of 1 rugae. Conversely, the rarest rugae shape in the daughters group was the right and left circular type, with a total of three rugae, a mean of 0.06 ± 0.233, a minimum count of 0, and a maximum count of one rugae.

Table 4. Statistical Comparison of Palatine Rugae Shape Distribution Between Mother and Daughter Groups

Shape		Mean Rank		*P-Value*
		Mother	Child	
Curve	Right	54.35	52.65	0.759
	Left	52.10	54.90	0.609
Wave	Right	47.53	59.47	0.038
	Left	45.32	61.68	0.005
Straight	Right	55.81	51.19	0.404
	Left	56.48	50.52	0.285
Circular	Right	54.00	53.00	0.697
	Left	54.53	52.47	0.452
Convergent	Right	53.50	53.50	1,000
	Left	54.06	52.94	0.743
Divergent	Right	52.88	54.12	0.783
	Left	52.62	54.38	0.729

The bivariate analysis according to the data presented in Table 4, comparing the mean ranks of palatine rugae shape patterns between mothers and their daughters showed no significant differences for most shapes, including curve, straight, circular, convergent, and divergent shapes on both the right and left sides ($p > 0.05$). This indicates that these rugae shape patterns are similar between mothers and daughters, suggesting a strong resemblance between these morphological traits across generations. The only exception in this analysis was the *wave* pattern, which exhibited statistically significant differences on both sides ($p = 0.038$) and left side ($p = 0.005$). The higher mean ranks observed in daughters compared to mothers indicate that the wave pattern is more predominant or frequently observed in daughters.

A Previous study on palatal rugae in Bangladeshi parent-offspring pairs, similarly found notable variability in wavy patterns despite general maternal resemblance[18]. They suggested a polygenic inheritance model. In which multiple genes interact, allowing phenotypic expression to fluctuate based on non-genetic influences. The results of the current study further validate this hypothesis, indicating that not all rugae forms follow Mendelian simplicity, and that epigenetic and lifestyle factors may act as modifiers, especially for non-dominant traits such as wavy and fragmentary types.

The role of Minangkabau matrilineality offers a unique perspective on the Maternal alignment observed in rugae traits. In this society, where lineage, inheritance, and social identity are traced through the mother, daughters are not only biologically linked but also culturally patterned to reflect maternal attributes. Cultural structures can indirectly reinforce biological expressions by standardizing environmental exposure, diet, and familial roles[21].

This cultural consistency likely contributes to the strong maternal resemblance observed in most rugae types, particularly the stable inheritance of primary and secondary rugae, and may even mitigate some environmental variability that could arise in other social structures.

Interestingly, the wave pattern was the only rugae shape that demonstrated statistically significant differences between the two group on both the right ($p=0.038$) and left ($p=0.005$) sides The higher mean ranks in daughters suggest an increased frequency or prominence

of this pattern in younger generations. Several interpretations can be made from this observation. First, this may indicate a generational shift in morphological dominance, potentially influenced by subtle genetic drift, epigenetic regulation, or environmental factors affecting intrauterine development.[24] Second, this finding may indicate maternal inheritance with phenotypic amplification, wherein certain inherited traits become more pronounced in the offspring, particularly under stable genetic transmission conditions.[25]

This result supports earlier findings that emphasize the heritability of specific rugae patterns, particularly in matrilineal societies such as the Minangkabau, where maternal lineage plays a central cultural and possibly biological role. However, the deviation observed in the wave pattern's expression also raises questions about other contributing factors, including microevolutionary processes, dietary changes, and local environmental adaptations. The forensic value of palatal rugae as identifiers in cases of mass disaster, advanced decomposition, or when DNA is unavailable, has been thoroughly demonstrated[22]. Stable traits such as primary and straight rugae can serve as core biometric anchors, while more variable traits such as fragmentary or wavy forms may assist in fine-grained discrimination or familial verification. Moreover, the discovery of non-classical or atypical rugae patterns—even if not statistically significant—underscores the need for updated classification systems that reflect ethnic and regional morphotypes. Previous research has advocated for the expansion of rugae taxonomy to include population-specific expressions, particularly in diverse anthropological contexts such as Indonesia[19].

CONCLUSION

This study confirms that palatal rugae patterns, particularly primary and secondary types, exhibit strong morphological similarities between biological mothers and daughters of the Minangkabau ethnic group, supporting their value as hereditary and forensic markers. The significant difference observed in the wave pattern, which was more frequent among daughters, indicates possible influences of environmental or epigenetic factors.

These findings highlight the importance of incorporating cultural and genetic contexts into forensic and anthropological research. Future studies with larger samples and genomic analyses are recommended to deepen the understanding of palatal rugae inheritance and variation.

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