Scoping Review

Identification of palatine rugae in forensic odontology in the Indonesian population: a scoping review

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ABSTRACT

Introduction: The study of palatine rugae in forensic odontology has become increasingly vital as a means of identifying individuals, particularly in scenarios where conventional identification methods prove inadequate. This scoping review focuses on the identification of palatine rugae in the Indonesian population. **Method:** A scoping review was conducted using the Arksey and O'Malley framework and PRISMA-ScR guidelines. Relevant articles were sourced from PubMed, ScienceDirect, and Google Scholar using Boolean operators and relevant keywords. Studies were included if they involved Indonesian populations, used palatal rugae for identification, were original research, published in Indonesian or English, and available in full text between March 2014 and March 2024. We excluded review articles, non-human studies, and papers in other languages. Two independent reviewers screened and selected articles. **Results:** The results of the scoping review identified various classifications of palatine rugae, with three articles using the Thomas and Kotze method and one article each using the Kapali, Trobo, Lysell, and Carrea methods. Two articles studied rugae inheritance, and one examined post-orthodontic stability. The widely used Thomas and Kotze method focuses on the length, shape, and direction of the rugae but has limitations in sex determination. Additionally, the Trobo, Kapali, Lysell, and Carrea classifications are also used due to their simplicity and clarity. This study investigated the pattern of palatine rugae and found that the pattern remains consistent before and after orthodontic treatment and is inherited from parent to child. The study also identified potential language bias, limited Indonesian literature on palatine rugae, and methodological variations across research articles. **Conclusion:** This scoping review affirms the reliability of palatine rugae in forensic odontology in Indonesia, highlights the need for further research to enhance understanding of rugae patterns and inheritance mechanisms, and contributes to the knowledge base for future forensic research and investigations.

KEYWORDS

Identification odontology forensic, palatine rugae, Indonesian population

INTRODUCTION

Forensic odontology is a specialized field in dentistry that plays a central role in applying various medicolegal identification methods.[1] Emam's study highlighted the importance of forensic odontology in identifying deceased individuals when visual or other identification methods are unavailable.[2] Shenoy's study emphasized that forensic odontology relies on data obtained from teeth and surrounding oral structures.[3] Jayakrishnan's study further elaborated that forensic odontology contributed to the identification of unknown human remains through dental records, bite marks, fingerprints, lip prints, palatine rugae prints and the analysis of skeletons at archaeological sites to determine lifestyle, diet, age, gender, height, and race.[4] Although forensic odontology significantly contributes to individual identification, its

success depends heavily on the quality of available data and the physical condition of the remains.

Shangguan, et al stated that palatine rugae have increasingly been used as a new biometric feature in forensic odontology identification.[5] Hingad et al suggested that palatal rugae (palatoscopy or rugoscopy) serves as an alternative method for human identification, particularly in cases such as traffic accidents, mass disasters, acts of terrorism, and other emergency situations.[6] Rugae begin to form around the third month of intrauterine life from the connective tissue lining the palatine process of the maxillary bone, with their development and growth influenced by reciprocal interactions between epithelial and mesenchymal cells through the expression of specific molecules in the extracellular matrix.[7] Additionally, Choube suggested that post-developmental, palatal rugae, like fingerprints, remain morphologically stable throughout a person's life.[8] Thus, palatine rugae have great potential as identification aids in various forensic cases.

Chong et al explained that palatal rugae, or plicae palatine, are irregular and asymmetrical connective tissue protrusions located behind the incisive papilla, extending from the anterior part of the hard palate to the mesial aspect of the first permanent molars without crossing the midline.[9] Armstrong et al revealed that palatine rugae exhibit high uniqueness both between species and between individuals, with humans typically havig 2-7 folds that vary in shape and number on each side.[10] The rugae pattern can be considered as a "fingerprint of the palate", as it varies and is unique to each individual, reflecting distinctive design and structural characteristics similar to fingerprints.[1] Although palatal rugae analysis shows promise as an identification tool, its validity as an individual unique marker requires further investigation.

Physiologically, palatal rugae play a role in the oral stage of swallowing by enhancing the interaction between food and taste receptors on the dorsal surface of the tongue, as well as contributing to speech and sucking functions. [11] Zhang et al. (2020) summarized that palatine rugae are a human biological trait that is difficult to replicate.[12] and serve as a reliable, cost-effective, and non-invasive tool.[13]

In addition, the study of Farronato et al reported that palatine rugae, as a marker with unique pattern of individuality for each person, have been confirmed even in monozygotic and dizygotic twins.[14] A relevant study by Fitri et al demonstrated that palatal rugae exhibited remarkable durability, persisting up to seven days after death and withstand extreme temperatures, such as those associated with third-degree burns.[15] These findings highlight the forensic reliability of palatal rugae, although further validation across populations is still required.

Currently, various studies demonstrate that palatal rugae patterns vary between individuals, including differences based on gender and specific populations. For example, Naeem et al noted that existing research literature has shown variations in rugae patterns with respect to gender.[16,17] Hussein et al analyzed palatal rugae patterns in Egyptians and Malaysians to differentiate the two groups based on gender, using a statistical model that predicts ethnic origin with moderate accuracy-approximately 65% for men and 54% for women.[17]

Meanwhile, Elrewie et al found that, among Egyptians aged 20-30 years, primary rugae outnumbered secondary rugae, and the dominant shape was wavy, followed by straight rugae.[18] Although numerous international studies highlight the potential of palatine rugae as a reliable identification marker, research focusing on their application within the Indonesian population remains limited. The morphological diversity of Indonesia's ethnic groups underscores the importance of understanding population-specific variations in rugae patterns to strengthen forensic identification methods.

The novelty of this study lies in its systematic mapping of the existing literature on palatine rugae identification specifically within the Indonesian population, synthesizing various classification systems, inheritance patterns, and stability findings to build a foundation for population-based forensic databases. The aims of this scoping review is to examine the use of palatine rugae in forensic odontology

among Indonesians, identify gaps in existing evidence, and highlight potential directions for future research to enhance the accuracy and applicability of rugae-based identification in Indonesia.

Methods

This literature study employed a scoping review approach to explore the use of palatine rugae for identification in forensic odontology within the Indonesian population. The inclusion criteria focused on studies involving Indonesian populations that used palatine rugae for forensic identification and employed original research designs, such as observational studies, case reports, clinical trials, and randomized controlled trials. Eligible studies were required to be published in either Indonesian or English and have full-text access available. Exclusion criteria included studies published in other languages, review articles, and research involving non-human subjects.

These criteria were established to ensure the study maintained relevance to forensic applications within the Indonesian context and focused on direct human identification methodologies. The review followed the structured framework developed by Arksey and O'Malley, ensuring a systematic evaluation and organisation of information. Additionally, the PRISMA-SCR method was also employed to identify and screen relevant papers. The research question focused on the identification of palatal rugae in forensic odontology within the Indonesian population.

The study utilised PubMed, Science Direct, and Google Scholar to obtain relevant literature published between 2014 and 2024. Boolean operators such as AND, OR, and NOT were applied to refine the search results, and language filters limited the studies to those published in Indonesian or English. Additionally, search strings included variations of "palatal rugae," "forensic odontology," and "Indonesian population" to ensure comprehensive retrieval of relevant literature.

Each database search employed specific keywords, as detailed in Table 1. Each author reviewed the results independently, and two independent reviewers worked in duplicate to screen articles for duplication, assess relevance based on title and abstract, and conduct full-text review. Disagreements were resolved through consensus discussions. Automation tools were not used in the selection process, ensuring a manual and thorough evaluation of each study.

Table 1. Search strategy

Data Base	Search Strategy
PubMed	"((((Identification) AND ((palatine rugae) OR (palatal rugae)) AND ((forensic odontology) OR (dental forensics)) AND ((Indonesian population))))"
ScienceDirect	Title, abstract or author-specified keywords: "((((Identification) AND ((palatine rugae) OR (palatal rugae)) AND ((forensic odontology) OR (dental forensics)) AND ((Indonesian population))))"
Google Scholar	"Identification of Palatine Rugae in Forensic Odontology in Indonesian Population "

Specific selection criteria were applied to identify relevant literature. The study focused on articles published within the last ten years, specifically between March 2014 and March 2024. Only full-text, open-access articles were included to ensure accessibility and ease of analysis. The scope was further limited to research published in Indonesian or English, focusing on the specific application of palatal rugae as a method of identification. Only studies involving Indonesian populations were considered to maintain relevance to the study's objectives. A variety of research types were included, such as original research, observational studies, case reports, clinical trials, and randomized controlled trials. In contrast, studies conducted in languages other than Indonesian or English were excluded, as were

review articles and any articles that did not utilise palatal rugae as an identification method. Finally, studies conducted on non-human subjects were also excluded to ensure a focus on the human application of palatal rugae in forensic identification.

Data extraction was conducted using Table 2, which presents a summary of key information from the selected studies. The extracted data includes details on the researcher, article title, ethnicity of the studied population, methods used for palatal rugae identification, total sample size, study design, and a brief summary of the findings. The data were then categorized thematically based on key aspects such as classification methods, inheritance patterns, and stability of palatine rugae. This thematic organization enhances clarity and allows for a structured interpretation of findings. Visual tools, including tables and thematic maps, were used to present the data effectively. Data interpretation involves collecting, summarizing, and reporting results based on relevant research characteristics. As this study was a scoping review, no formal ethics review was required.

RESULTS

The article search, based on the keywords: Identification AND palatine rugae OR palatal rugae AND forensic odontology OR dental forensics AND Indonesian population, initially identified 118 articles. Specifically, 13 articles were retrieved from PubMed, 94 articles from ScienceDirect, and 10 articles from Google Scholar, totaling 118 articles. After conducting duplication check, 114 articles were obtained. The first screening, based on the inclusion criteria, identified 8 relevant articles. A second screening, involving a full-text review, further narrowed this to 6 articles. The process of article search and selection of studies is illustrated in figure 1.

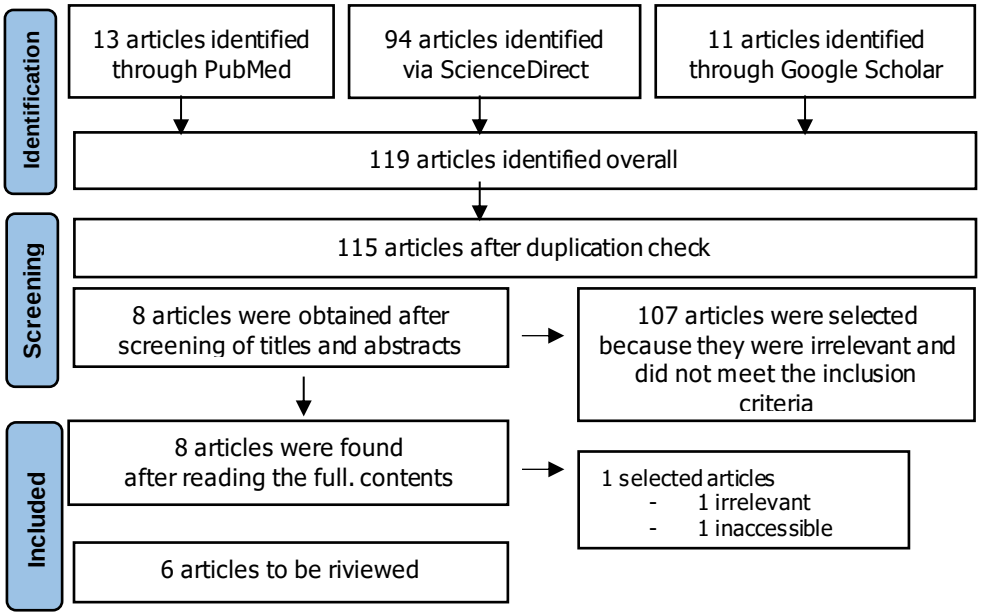

Figure 1. Flowchart of searching articles using PRISMA-Scr

The following stage of this research is presented in Table 2, which summarizes the results and observations from selected studies investigating the identification of palatal rugae in forensic odontology in the Indonesian population. Although the included articles use various classification schemes, the Thomas and Kotze classification (1983) emerges as the most widely used method in Indonesia. Additionally, one study applies the Kapali classification, another uses the Trobo classification, one adopts the Lysell classification, and another follows the Carrea classification. Beyond classification, several studies also explore other aspects of palatal rugae, such as hereditary patterns passed from parents to children and the stability of rugae structures after orthodontic treatment. These findings highlight the

diversity of classification approaches and reinforce the relevance of palatal rugae as a forensic identification tool in Indonesia.

Table 2. Data analysis presentation

No	Researcher	Article title	Ethnicity	Palatine rugae method	Total of samples	Study design	Summary
1	Ardy, OM (2016).	Differences in Reliability of Lip Print Pattern and Palatal Ruga Pattern in Sex Determination	Surabaya	Thomas and Kotze's classification	68 samples (34 male and 34 female) 21-30 years old	Analytical Observational Research.	There is a relationship between lip print patterns and gender. There is no relationship between the palatal rugae pattern and gender.
2	Suhartono, *et.al.* (2016)	Palatal rugae patterning in a modern Indonesian population	Jawa, Sunda, Tionghoa Indonesia, Batak,Melayu , Madura, Betawi, Minahasa, Gorontalo, Ambon,dan Ternate	Trobo Classification	100 samples (47 male and 53 female), aged 13 -75 years old	Observational research	The line, meander, and curve rugae types, which account for around 83% of the total, are the dominant shapes and are considered to be fairly representative of the Indonesian population.
3	Saputra, Sintia & Endah, Mardiati & Pribadi, Indra & Malinda, Yuti. (2018).	Differences in palatine rugae patterns before and after treatment with removable orthodontic appliance	Indonesia	Lysell classification and Carrea's classification	111 samples (26 men and 85 women) Age 18-30 years	Observational research	The most common pattern of palatal rugae observed before and after orthodontic treatment is primary rugae with posteroanterior direction; no significant difference was found before and after orthodontic treatment.
4	Rania, Nada & Kusuma, Nila & Murniwati, Murniwati. (2018).	Differences in Palatine Rugae Shape and Size Between Fathers and Sons of Minangkabau Men in Luhak Nan Tigo Region	Minangkabau	klasifikasi Thomas-Kotze dan klasifikasi Kapali	78 pairs of fathers (aged 39 - 65 years) and children Male siblings (aged 13 - 48 years)	analytic observational with a cross-sectional approach.	There was no significant difference in the number of palatal rugae between biological fathers and sons based on rugae shape. However, a significant difference was observed in the number of palatal rugae between fathers and biological sons of the Minang tribe based on rugae size
5	Prastyo, Eko & Zulfatunnadiroh, Ledy & Nirbita, Sharly. (2020).	Palatine Rugae Patterns in the Osing Population	Osing (Banyuwang)	klasifikasi Kapali	age 20-40 years	descriptive observational.	In the Osing population, analysis based on shape and pattern showed that the curved palatal rugae was the most common while circular palatal rugae were the least common.
6	Ramadhan, Muhammad & Sukmana, Bayu indra & Erlita, Isyana & D.H., Irnamanda & Huldani, Huldani. (2024).	Inheritance of Parents' Palatine Rugae to Children as a Means of Forensic Odontology Identification in Banjar Ethnicity	Banjar	Thomas and Khotzen's classification	32 families with complete fathers, mothers, and children, totalling 96 samples.	This research is a cross-sectional analytic method.	The most dominant palatal rugae pattern among children, mothers, and fathers in the Banjar Ethnic group is the wavy pattern. The palatal rugae pattern is significantly and strongly inherited from parents to children, whether from father to child or mother to child.

DISCUSSION

Palatal rugae were first identified by Winslow in 1732, with the first recognizable illustration created by Santorini in 1775. In 1889 Harrison Allen, became the first to advocate for the use of palatal rugae in individual identification.[19] The study of palatal rugae for establishing identity is referred to as rugoscopy or palatoscopy, a method first proposed in 1932 by the Spanish investigator Trobo Hermosa.[20] Palatal rugae begin to develop during the third month of intrauterine life, while their size may change with growth, their shape remains stable, with approximately 93% persisting even in individuals with third-degree facial burns.[21] Each individual

possesses unique palatal rugae pattern and orientations.[22] Based on the results of this scoping review, palatal rugae have been confirmed as a valuable tool for identification in forensic odontology.

Several classification methods have been developed to assess palatal rugae patterns, each offering distinct perspectives on the intricate morphology of these structures. Gloria et al categorized rugae based on their number and extent in relation to teeth, further classifying them into simple and developed types.[21]Trobo et al identified two main patterns: simple-subdivided into point-shaped, line-shaped, curve-shaped, wavy, sinuous-shaped, and circular-shaped-and compound, where two or more patterns coexist.[23] Carrea's classification focused on the direction of the rugae, categorizing them into posterior-anterior, perpendicular, anterior-posterior, and varied directions.[24] Martin dos Santos proposed a classification system based on both morphology and position, which include point, line, curve, angle, circle, sinuous, bifurcated, trifurcated, interrupt, and anomalous type.[25]

Lysell's classification focused on rugae length, dividing them into primary (≥mm), secondary (3-5 mm), fragmentary (2-3 mm), and less than 2 mm.[26] Thomas and Kotze developed a comprehensive system categorizing palatal rugae based on length (primary, secondary, fragment), shape (straight, curved, wavy, circular, or unified), and angle (positive, negative, zero).[27] Kapali's classification emphasized rugae shape, categorizing them as curved, wavy, straight, and circular.[26] Da Silva's classification categorized rugae based on form into simple type (numbered one to six) and compound types (combination of two or more patterns).[21] Finally, one classification based on rugae union pattern divided them into convergent or divergent types.[26] These diverse classifications provide a valuable framework for understanding the complexity and variability of palatal rugae patterns, contributing to the advancement of forensic odontology.

The scoping review revealed that the most widely used classification system for the Indonesian population is the 1983 Thomas and Kotze classification. This finding aligns with Kusuma's study, which also reported that the Thomas and Kotze classification is most frequently applied in research.[28] The Thomas and Kotze classification, a modification of the Lysell classification, is considered is applicable and reliable due to its multiple variables, such as rugae length, shape, direction, and union status -factors that contribute to its methodological advantage.[23] Furthermore, Naeem et al., noted that, among the various classifications system for palatal rugae systems, the Thomas and Kotze classification is regarded as the simplest, most practical, and most detailed in describing the morphological characteristics of palatal rugae.[16]

Despite its application, the Thomas and Kotze classification also has limitations. A literature study by Ardy, OM noted that this classification system cannot be used for gender determination, as it does not account for the unification of palatine rugae, a factor shown to enhance sex determination accuracy.[28] This limitation is further supported by Ahmed and Hamid's study, who reported that no significant sexual dimorphism in rugae dimensions, shape, and orientation was found when using rugae classification developed by Lysell, Thomas and Kotze.[29]

Although the Thomas and Kotze classification is widely used, some literature on the Indonesian population uses alternative systems. For example, Suhartono et al. used the Trobo classification to analyze palatal rugae patterns among various ethnic groups, including Javanese, Sundanese, Indonesian Chinese, Batak, Malay, Madurese, Betawi, Minahasa, Gorontalo, Ambon, and Ternate populations. The study found that approximately 83% of the rugae patterns consisted of line, meander, and curve types, which were considered to be representative of the Indonesian population.[30] The authors explained that the reason for using the Trobo classification is that it has commonly used supporting images, such as simple and compound type shapes, facilitating clearer identification of shape variations in palatal rugae.

Additionally, one of the reasons for using Trobo's classification is that Trobo was the first to advocate the study of palatine rugae based on their shape and introduced

the concept of 'Palatal Rugoscopy' in 1932; Trobo's classification is considered advantageous due to its simplicity and ease of application.[31] Furthermore, Faheem et al., suggested that Trobo's system uniquely divides rugae into simple and arranged types, represented by letters. This characteristic makes the classification distinctive, as it comprehensively covers a wide variety of palatal rugae shapes and configurations that are often overlooked by other classification systems.[32]

In the study by Prastyo, Eko & Zulfatunnadiroh, Ledy & Nirbita, Sharly the Osing (Banyuwangi) ethnic group in the Indonesian population was analyzed using the Kapali classification. This finding showed that the curved palatal rugae were the most prevalent pattern among the Osing population, while the circular palatal rugae were the least common.[33] Additionally, Rania et al., suggested that Kapali's 1997 classification was a modification of the Lysell and Thomas and Kotze systems, incorporating both rugae unification and shape.[34]

Inheritance of palatal rugae patterns from parent to child has been documented in several studies, highlighting the consistency of rugae pattern transmission across generations. Further research has explored both genetic and environmental factors influencing these unique anatomical structures. Patel et al*.,* reported that the development of palatal rugae begins at 12-14 weeks of intrauterine life and remains unchanged even after death.

The formation of palatine rugae occurs through interactions between the epithelium and mesenchyme during embryogenesis and characterized by morphological stability, despite variations in position and length. The regulation of fiber orientation during morphogenesis has been found to be closely associated with the specific genetic influence .[35] Additionally, Chong et al., investigated heritability of rugae pattern morphology among siblings and concluded that both environment and genetics factor play a role. The study found that a greater genetic relationship between individuals increases the likelihood of rugae patter stabililty.[9]

Genes, as components of DNA, are inherited from parent to child and contribute to the transmission of biological traits, including palatine rugae patterns. Mala et al. (2017) reported that palatine rugae, when analyzed within families, showed significant correlations between parents and their children.[36] This is in line with the study of Rania et.al (2018), included in this scoping review, found that within the Minangkabau ethnic population in Indonesia, there was no significant difference in the number of palatal rugae between biological fathers and sons when analyzed based on shape.[34]

Furthermore, this finding is supported by Ramadhan et al. (2024), who found that within the Banjar ethnic group in Indonesia, the rugae patterns are inherited significantly and strongly from parents to children, whether from father to child or from mother to child.[37] Additionally, Bhatnagar (2024) explained that although palatine rugae show high heritability in familial relationships between parents and offspring, noth genetic and environmental factors can affect the development and variation of rugae patterns.[38]

The stability of palatal rugae patterns, particularly their resistance to change over time and external influences, has been a subject of interest in forensic odontology. Chong et al. (2020) suggested that palatal rugae serve as stable superimposition markers to guide tooth movement in orthodontics and are valuable aids in forensic identification.[9] Additionally, Saputra et al., as found in this scoping review, reported that the most common palatine rugae pattern observed before and after orthodontic treatment is the primary rugae with posteroanterior direction, showing no significant difference pre- and post-treatment.[39] However, the stability of palatal rugae remains a topic of debate. Smitha 2021noted that while orthodontic treatment caused a slight increase in rugae length, the shape remained stable, suggesting only limited alterations.[40]

While this scoping review provides valuable insights, several potential biases and limitations should be acknowledged. This study did not implement a formal quality assessment tool, such as ROBINS-I for observational studies, which could have provided a clearer evaluation of study reliability. The variability in study designs,

sample sizes, and population characteristics across different studies also contributes to potential bias. Future studies should incorporate structured bias assessments to improve validity and reliability. Additionally, the body of literature focusing on the Indonesian population is still limited, and the use of non-standardized methodologies across studies complicates direct comparisons. Moreover, the role of environmental and genetic factors in shaping palatine rugae patterns remains underexplored, especially in relation to Indonesia's diverse ethnic groups.

Despite certain limitations, palatal rugae remain a promising tool for forensic identification. To enhance their application, future research should adopt more standardized methodologies and explore genetic and environmental influences more deeply. This study is limited by its reliance on existing literature, which varies in methodological quality and sample representation, potentially affecting the generalizability of the findings. The exclusion of unpublished or non-English studies may also introduce publication bias. Additionally, the diversity of classification methods used across studies makes it difficult to draw consistent conclusions. While AI-based rugae pattern recognition shows potential, its practical application and validation in forensic casework still require further investigation.

CONCLUSION

This scoping review affirms the reliability of palatine rugae in forensic odontology in Indonesia, emphasizing their unique patterns and usefulness in human identification. It highlights the need for further research to enhance understanding of rugae patterns, inheritance mechanisms, and their practical applications in forensic science. The review also contributes to the growing knowledge base supporting the role of palatine rugae in forensic investigation. The implication of these findings is that palatine rugae patterns can serve as a reliable forensic identification tool due to their genetic inheritance and stability from prenatal age. Despite potential environmental influences, their persistence before and after orthodontic treatment supports their forensic applicability. Additionally, identifying shape variations across populations highlights the need for refining classification systems and developing population-specific forensic databases. Further research integrating palatine rugae analysis with other biometric identification methods could enhance forensic accuracy.

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