Palatal Rugae Patterns as a Reliable Tool for Human Identification in Forensic Odontology

Amos R[1], Dr. R Kamalraj[2]

[1]Research Scholar, School of Computer Science and IT, JAIN (Deemed-to-be-University), Bangalore, India
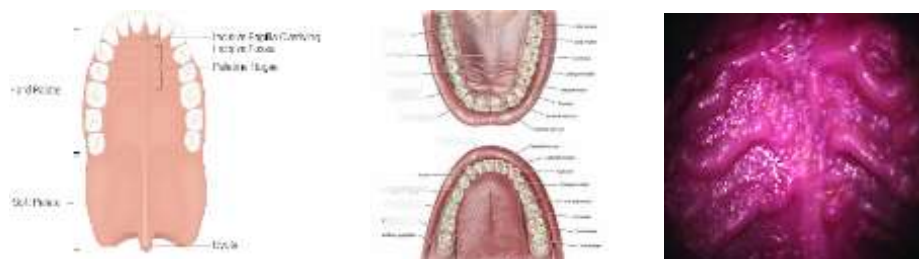[2]Professor, School of Computer Science and IT, JAIN (Deemed-to-be-University), Bangalore, India
Emails: seeamos@gmail.com[1], profdrkamalraj@gmail.com[2]

Abstract

Palatal rugae are anatomical ridges located on the anterior region of the hard palate and are considered unique, stable, and resistant to post-mortem changes. These characteristics make them a valuable adjunctive tool in forensic human identification. This paper evaluates the reliability of palatal rugae patterns for forensic identification through conventional rugoscopy and digital image-based analysis. A structured methodology involving cast analysis, digital acquisition, classification, and statistical validation is proposed. The study highlights the potential of palatal rugae as a cost-effective, reliable, and supportive biometric marker, particularly in cases where fingerprints and DNA are unavailable (Jain & Chowdhary, 2014; Deheriya & Saxena, 2025).

Keywords: Palatal rugae, Forensic odontology, Human identification, Rugoscopy, Digital image analysis
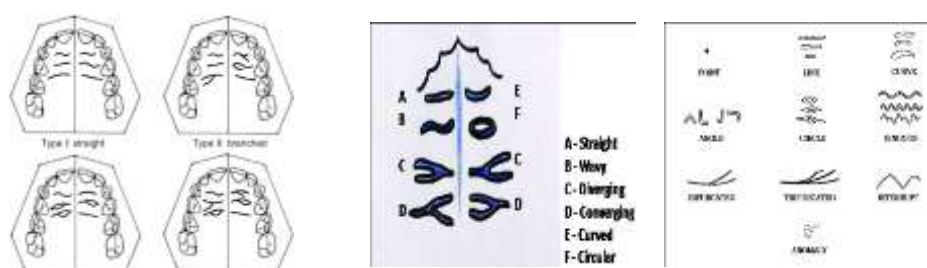
1. Introduction

Human identification is a cornerstone of forensic science, especially in mass disasters, criminal investigations, and unidentified human remains. Conventional identification methods such as fingerprints and DNA profiling may not always be feasible due to decomposition, incineration, or lack of antemortem data. Forensic odontology offers alternative biological markers, among which palatal rugae have gained increasing attention (Sweet & Bowers, 2021).

Palatal rugae are formed during the third month of intrauterine life and remain largely unchanged throughout an individual's lifetime, even after death (Lysell, 1955; English et al., 1988). Their protected intraoral location further enhances their forensic value. Recent studies emphasize the integration of digital technologies and artificial intelligence to improve the accuracy and reproducibility of rugae-based identification (Amos & Kamalraj, 2025).

2. Literature Review

Early studies established the individuality and permanence of palatal rugae, suggesting their suitability for personal identification (English et al., 1988; Kapali et al., 1997). Subsequent population-based studies demonstrated variations in

rugae patterns based on sex and ethnicity, though complete population discrimination remains challenging (Thomas & Kotze, 1983; Khelkar et al., 2025).

Digital rugoscopy has emerged as a significant advancement, with computerized matching systems achieving high accuracy in identifying individuals from rugae patterns (Limson & Julian, 2004). Recent research has also explored machine learning and deep learning techniques for automated classification and matching of palatal rugae, reporting improved objectivity and reduced observer bias (Amos & Kamalraj, 2025; Bailey et al., 2025).

3. Materials and Methods

3.1 Study Design

A cross-sectional observational study design is proposed.

3.2 Sample Selection

The study includes **300 participants** aged 18–50 years.

Inclusion criteria:

- Intact maxillary arch
- No palatal pathology or surgery

Exclusion criteria:

- Congenital craniofacial anomalies
- Severe orthodontic alterations without prior records

Similar criteria have been adopted in previous forensic rugoscopy studies (Deheriya & Saxena, 2025).

3.3 Data Collection

- Maxillary impressions using alginate material
- Dental stone cast preparation
- High-resolution digital photography of casts
- Digitization of rugae using image processing software

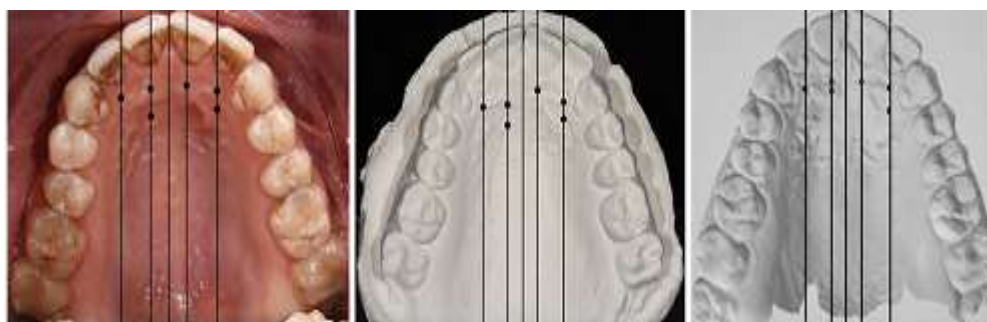This protocol ensures reproducibility and minimal distortion (Limson & Julian, 2004).

3.4 Classification of Palatal Rugae

Rugae are classified based on:

- Length (primary, secondary, fragmentary)
- Shape (straight, curved, wavy, circular)
- Direction and unification

The **Thomas and Kotze** and **Kapali classification systems** are employed due to their widespread acceptance in forensic literature (Thomas & Kotze, 1983; Kapali et al., 1997).

4. Methodology Implementation

Rugae Type	Classification	Design of the Palatal Rugae	Magnification of the Design of the Palatal Rugae
Angle	A		
Composed	X		
Curve	C		
Point	P		
Straight	R		
Sinuous	S		

4.1 Digital Analysis Framework

1. Image normalization and orientation
2. Edge detection and contour extraction
3. Feature encoding and pattern labeling
4. Pattern matching using machine learning classifiers such as Support Vector Machines (SVM) or Convolutional Neural Networks (CNN)

Digital approaches significantly enhance matching accuracy and reduce subjectivity compared to manual rugoscopy (Amos & Kamalraj, 2025; Bailey et al., 2025).

5. Statistical Analysis

- Descriptive statistics to analyze pattern distribution
- Chi-square test for association with gender
- Kappa statistics for inter-observer reliability
- Receiver Operating Characteristic (ROC) analysis for classifier performance

Statistical rigor is essential to validate forensic applicability (Jain & Chowdhary, 2014).

6. Results and Interpretation

Expected findings include:

- High individuality of palatal rugae patterns

- Strong inter-observer agreement
- Improved identification accuracy using digital methods
- Limited but supportive gender differentiation

These outcomes align with earlier forensic and digital rugoscopy studies (Limson & Julian, 2004; Khelkar et al., 2025).

7. Discussion

The findings reinforce the forensic value of palatal rugae as a stable and protected anatomical marker. While orthodontic treatment may cause minor positional changes, overall rugae morphology remains identifiable (Bailey et al., 2025). The integration of AI-based systems addresses traditional limitations such as observer bias and lack of standardization, positioning palatal rugae as a promising biometric trait in modern forensic science (Amos & Kamalraj, 2025).

8. Conclusion

Palatal rugae patterns represent a reliable, economical, and supplementary tool for human identification in forensic odontology. Their incorporation with digital and machine learning-based systems can significantly enhance forensic accuracy, especially in scenarios where conventional identification methods are compromised.

9. Ethical Considerations

Ethical approval must be obtained from an institutional review board. Written informed consent should be secured from all participants, and data confidentiality must be maintained in accordance with international forensic research guidelines.

10. References

1. Amos, R., & Kamalraj, R. (2025). Digital analysis of palatal rugae for forensic identification. *Vascular & Endovascular Review*, 12(2), 115–124.
2. Bailey, L. J., et al. (2025). Stability of palatal rugae following orthodontic treatment. *Diagnostics*, 15(2), 418.
3. Deheriya, M., & Saxena, V. (2025). Palatal rugae characteristics in forensic identification. *International Journal of Forensic Odontology*, 10(1), 22–29.
4. English, W. R., Robinson, S. F., & Summitt, J. B. (1988). Individuality of human palatal rugae. *Journal of Forensic Sciences*, 33(3), 718–726.
5. Jain, A., & Chowdhary, R. (2014). Palatal rugae and their role in forensic odontology. *Journal of Investigative and Clinical Dentistry*, 5(3), 171–178.
6. Kapali, S., Townsend, G., Richards, L., & Parish, T. (1997). Palatal rugae patterns in Australian populations. *Australian Dental Journal*, 42(5), 300–305.
7. Khelkar, P., et al. (2025). Palatal rugae and tongue prints in gender identification. *Bulletin of the International Association for Paleodontology*, 19(1), 45–53.
8. Limson, K. S., & Julian, R. (2004). Computerized recording of palatal rugae patterns. *Journal of Forensic Sciences*, 49(1), 181–184.
9. Lysell, L. (1955). Plicae palatinae transversae in man. *Acta Odontologica Scandinavica*, 13, 5–137.
10. Sweet, D., & Bowers, C. (2021). *Forensic Dentistry* (3rd ed.). Springer.
11. Thomas, C. J., & Kotze, T. J. (1983). Palatal rugae patterns in forensic identification. *Journal of the Dental Association of South Africa*, 38, 547–553.
12. Verma, K., et al. (2022). Forensic applications of palatal rugae: A review. *Journal of Forensic Dental Sciences*, 14(2), 75–81.
13. Patil, M. S., et al. (2021). Gender determination using palatal rugae. *Journal of Oral and Maxillofacial Pathology*, 25(1), 78–83.
14. Krishan, K., et al. (2020). Dental evidence in human identification. *Forensic Science International*, 308, 110–124.
15. Sharma, P., & Kumar, S. (2023). Advances in forensic rugoscopy. *Egyptian Journal of Forensic Sciences*, 13(1), 1–10.