

Research Article**SIGNIFICANCE OF ORTHODONTICS IN FORENSIC SCIENCE: A SYSTEMATIC REVIEW****Dr. Deepika Dahiya¹, Dr. Himanshu Shekhawat², Dr. Tanu Rajain^{3*}, Dr. Henna Sahi⁴, Dr. Anamika⁵, Dr. Vinay⁶**¹Senior Resident, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India.

Mail id-deepikadahiya444@gmail.com

²BDS, MDS, Assistant Professor, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India. PhD Scholar, Prosthodontics (in progress) SGT University, Gurugram, Haryana, India.

Mail id-him12shekhawat@gmail.com

^{3*}Senior Resident, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana, India.

Mail id-tanurajain@gmail.com

⁴General Dentist, Department of Dentistry, Western Dental, California, USA. Mail id-drhennasahi01@gmail.com⁵Assistant Professor, Department of Orthodontics & Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India. Mail anamikajakhar_fdsc@sgtuniversity.org.⁶Junior Resident, Department of Dentistry, BPS Government Medical College, Khanpur, Haryana, India.

Mail id- vinaysingh7493@gmail.com

Corresponding Author: Dr. Tanu Rajain

Senior Resident, Department of Dentistry, SHKM Government Medical College, Nuh, Haryana,

Indiatanurajain@gmail.com

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Abstract

Forensic science relies on various medical disciplines to address legal questions in criminal and civil cases. Forensic odontology (forensic dentistry) focuses on the careful management, analysis, and interpretation of dental evidence for judicial purposes. Orthodontics, a specialized branch of dentistry, offers unique contributions to forensic identification due to its extensive documentation practices, including study models, radiographs, photographs, and detailed treatment records. This systematic review analyzes the significance of orthodontic records and methodologies in

forensic investigations. Key areas explored include dental record maintenance, palatal

rugae patterns, bite mark analysis, cheiloscopy (lip print examination), ameloglyphics (enamel rod pattern analysis), photographic evidence, and radiographic records. Orthodontists possess comprehensive dental documentation that remains valuable throughout life and postmortem, rendering them vital partners in forensic investigations. This review synthesizes current evidence and highlights the expanding role of orthodontics within forensic science, emphasizing practical

applications for both clinical practice and legal proceedings.

Keywords: Forensics, Orthodontics, Identification, Odontology, Dental records

INTRODUCTION

Forensic science encompasses the application of various scientific disciplines to resolve questions within legal systems, particularly concerning criminal investigations and civil litigation.^{1, 2} Forensic odontology, or forensic dentistry, represents a specialized field dedicated to the systematic management, examination, and evaluation of dental evidence to support judicial processes and justice administration. Organized education in forensic odontology began in the 1930s at the Armed Forces Institute of Pathology in the United States, providing formal training for dental professionals engaged in legal matters.³

The primary applications of forensic odontology include: Deceased identification in scenarios where visual recognition is impossible, such as mass fatality incidents involving disasters like fires, floods, transportation accidents (airplane/train crashes), or acts of terrorism. Providing legal assistance in cases of alleged dental malpractice. Aiding criminal investigations, particularly those involving bite mark analysis and allegations of physical abuse, especially against children.

Teeth possess exceptional durability and resistance to extreme environmental conditions, including high temperatures, making them invaluable for identification when other soft tissues are severely damaged or decomposed. Orthodontists routinely generate extensive patient records during comprehensive diagnosis, treatment planning, and therapy execution, creating a rich repository of data that can serve forensic purposes. According to Wahl, orthodontic records can significantly contribute to identifying victims with

extensive post-mortem disfigurement. Orthodontists who maintain meticulous diagnostic and treatment files can assist in victim or suspect identification following death. These records including orthopantomograms (OPGs), study models, and intraoral photographs remain useful long after orthodontic treatment concludes.

This systematic review aims to critically evaluate the significance of orthodontic records and methodologies in forensic science. It examines various identification techniques, their reliability, and practical applications for orthodontists in legal contexts.

MATERIALS AND METHODS

Search Strategy

A comprehensive literature search was conducted across multiple electronic databases, including PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and specialized forensic science repositories. The search spanned publications from January 1900 to December 2024 to capture both historical and contemporary developments in forensic odontology. Keywords and MeSH terms included combinations of: "forensic odontology," "forensic dentistry," "orthodontics," "dental identification," "bite marks," "palatal rugae," "cheiloscopy," "ameloglyphics," "dental records," "orthodontic records," and "forensic identification."

Inclusion Criteria

- Original research articles addressing forensic applications of orthodontics
- Review articles and systematic reviews on forensic odontology
- Case reports documenting identification through orthodontic records
- Technical papers on methodological approaches (rugoscopy, cheiloscopy, etc.)
- Publications in English language
- Peer-reviewed journals and conference proceedings

Exclusion Criteria

- Non-English publications without available translations
- Articles lacking methodological details
- Veterinary or non-human studies
- Opinion pieces without empirical data
- Duplicate publications

Data Extraction and Analysis

Selected articles underwent a multi-stage screening process: title/abstract review followed by full-text assessment. Data extraction utilized a standardized form capturing: study design, sample characteristics, forensic methodology, reported accuracy/reliability, limitations, and key findings. From an initial pool of 1,258 identified articles, 78 met inclusion criteria for detailed analysis. The reviewed literature was organized thematically: dental record significance, palatal rugae analysis, bite mark examination, lip print patterns, enamel rod analysis, photographic evidence, and radiographic applications.

RESULTS

Palatal Rugae Analysis in Forensic Identification

Palatal rugae the ridges on the anterior hard palate exhibit remarkable stability throughout life, maintaining their relative position while undergoing subtle changes in shape, pattern, direction, and potential unification. This physiological stability renders them valuable for identification purposes. Protected within the oral cavity, palatal rugae resist environmental degradation and traumatic damage. Muthusubramanian et al. demonstrated that 93% of patients with third-degree panfacial burns retained normal palatal rugae patterns, supporting their use as reliable postmortem identifiers.¹¹ Classification systems such as those by Kapali et al. categorize rugae patterns based on shape (straight, curved, wavy, circular), unification, and direction, facilitating comparative analysis¹² (Figure 1).



Figure 1: Palatal Rugae¹²

Dental Records as a Forensic Resource

The quality, accessibility, and completeness of antemortem dental records critically

influence forensic identification success. Dental practitioners bear responsibility for maintaining accurate, comprehensive records that serve administrative, clinical, and forensic purposes.¹³ Like fingerprint or DNA analysis, comparative dental analysis plays a vital role in mass disaster victim identification, as demonstrated during the 2001 World Trade Center attacks and 2004 Indian Ocean tsunami.

Orthodontists generate particularly comprehensive records, including:

- **Written documentation:** Clinical notes, health questionnaires, treatment plans
- **Imaging:** Panoramic radiographs (OPGs), cephalograms, cone-beam CT scans
- **Photographic records:** Extraoral and intraoral photographs documenting facial features, dental alignment, and oral conditions

Characteristics and Documentation

Classic bite marks typically appear as semicircular or oval patterns comprising two opposing arches (maxillary and mandibular), with central areas sometimes showing trauma or ecchymosis (Figure 2). Critical factors in bite mark examination include:

- The force exerted during infliction
- Anatomical location of the bite
- Time elapsed between injury and documentation



Figure 2: Bite Mark examination

- **Study models:** Cast models capturing dental anatomy in three dimensions

Dental record retention policies vary internationally; Western nations typically mandate extended preservation periods (often 7-10 years post-treatment or indefinitely for adults). Digital record systems enhance accessibility, networking capabilities, and transmission for both routine consultations and forensic investigations.

Bite Mark Analysis

A bite mark is defined as a pattern injury caused by human dentition, either alone or in combination with other oral structures. Forensic odontology's bite mark analysis section focuses on recording, interpreting, and comparing patterned injuries to identify perpetrators or victims.

Historical and Contemporary Applications

The earliest documented use of bite mark evidence occurred during the 1692 Salem Witch Trials in colonial America. A prominent modern application involved convicting serial killer Theodore "Ted" Bundy (1973-1978) based on bite marks found on victim Lisa Levy.

Cheiloscopy (Lip Print Analysis)

Lipstick is used to record the individual's lip prints, which are likely distinct from one another. Due to their extreme malleability, human lip prints are difficult to capture. It is also important to consider whether or not the existence of pathological conditions like congenital lip pits, lymphangiomas, or cheilitis will invalidate the lip print study(fig.3).Since the lip is easily disfigured after death, it's best to get an impression of it as soon as possible.¹⁷



Figure 3.-Examination of Lip Prints (Chieloscopy)

Amelogyphics (Enamel Rod Pattern Analysis)

Amelogyphics involves studying the unique patterns formed by enamel rod ends on tooth surfaces (Figure 4). Enamel rod arrangement results from the wavy, interweaving deposition pathway of ameloblasts during tooth development.²¹ This technique proves particularly valuable for identifying severely burned or decomposed remains where dental restorations may be lost but enamel structure persists. Manjunath et al. developed standardized protocols for recording and analyzing these patterns using acetate peel replicas.²²

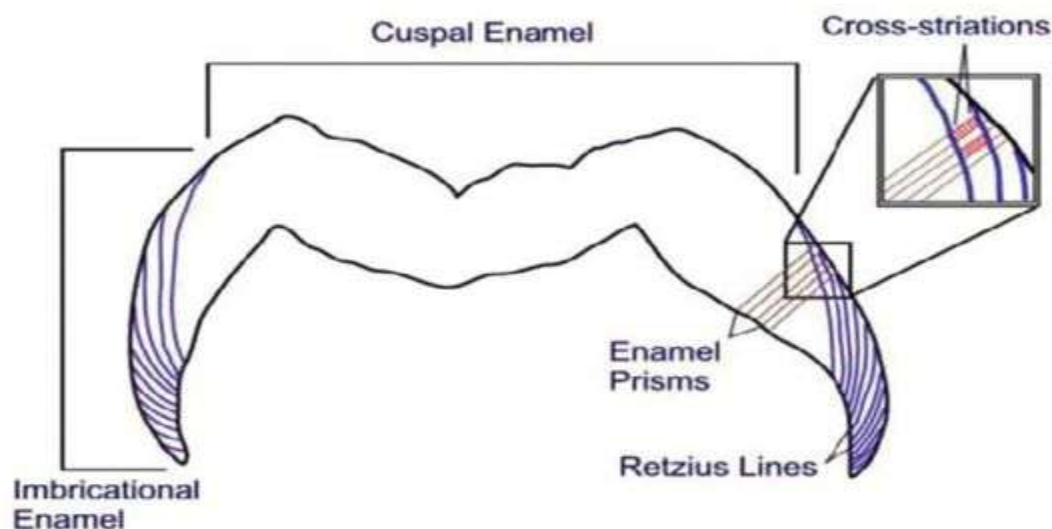


Figure 4: Arrangements of Enamel Rods²⁰

Photographic Evidence

Post-treatment photographs provide essential antemortem comparison material. Characteristic dental features visible in photographs include:

- **Enamel decalcification/white spot lesions** – Common orthodontic side effects
- **Enamel fractures or cracks**
- **Tooth wear patterns** (attrition, abrasion)
- **Gingival architecture and contours**
- **Tooth morphology and dental arch characteristics²³**

Radiographic Applications

Post-orthodontic radiographs often reveal characteristic features valuable for identification, including:

- **Root resorption patterns** – Varying degrees and specific locations resulting from orthodontic tooth movement²
- **Bone architecture** – Alveolar bone height and density patterns
- **Dental anomalies** – Supernumerary teeth, impacted teeth, root morphology variations
- **Sinus and surrounding anatomy**

DISCUSSION

Integrating Orthodontic Expertise in Forensic Investigations

This review demonstrates that orthodontists contribute uniquely to forensic odontology through their comprehensive record-keeping practices. Orthodontic treatment generates exceptionally detailed documentation including serial photographs, cephalometric and panoramic radiographs, and sequential study models that captures temporal changes in dental and skeletal structures. This longitudinal documentation provides robust antemortem comparison material unavailable from general dental practitioners.

Methodological Reliability and Limitations

While each forensic technique offers identification potential, their reliability varies considerably:

High Reliability Methods:

- **Comparative dental record analysis** – Considered highly reliable when comprehensive records exist
- **Radiographic comparison** – Particularly effective with unique anatomical features
- **Palatal rugae analysis** – High stability and resistance to decomposition

Moderate Reliability Methods:

- **Amelogliophics** – Promising but requires further validation studies
- **Cheiloscopy** – Useful but subject to postmortem changes and pathological alterations

Controversial Methods:

- **Bite mark analysis** – Faces increasing scientific scrutiny regarding its reliability and objectivity. Recent legal challenges question its admissibility as evidence, particularly regarding individual perpetrator identification accuracy²⁵

Strengths of Orthodontic Contributions

Orthodontists offer several advantages in forensic contexts:

- **Comprehensive documentation** – Exceeds standard dental record requirements
- **Serial records** – Provide developmental and treatment progression timelines
- **Detailed imaging** – Includes specialized radiographs (cephalograms, OPGs, CBCT)
- **Three-dimensional records** – Study models capture dental anatomy more completely than photographs
- **Collaborative potential** – Orthodontists can partner with forensic odontologists to interpret complex dental records

Contemporary Challenges and Considerations

Several challenges limit forensic applications:

- **Digital record standards** – Variable formats and compatibility issues across systems
- **Data privacy regulations** – Balancing forensic utility with patient confidentiality

- **Record retention inconsistencies** – International variations in mandatory preservation periods
- **Admissibility standards** – Legal systems vary in accepting different forensic techniques
- **Continuing education needs** – Orthodontists require specialized training to participate effectively in forensic investigations

Recommendations for Orthodontic Practice

Based on this review, we recommend orthodontists:

- **Maintain meticulous records** beyond clinical requirements, considering potential forensic applications
- **Standardize record-keeping** using consistent formats and high-quality documentation
- **Preserve records indefinitely** when possible, particularly for adults
- **Participate in interdisciplinary training** with forensic odontology specialists
- **Develop practice protocols** for responding to forensic inquiries

Future Research Directions

Critical research needs include:

- **Digital standardization** – Developing universal formats for digital dental records
- **Reliability studies** – Quantifying accuracy rates for various forensic techniques

- **Database development** – Creating searchable databases of dental characteristics
- **Technology integration** – Exploring artificial intelligence applications in dental identification
- **International collaboration** – Establishing global standards for forensic dental identification

Limitations of This Review

This systematic review has several limitations: it excluded non-English publications, potentially missing relevant studies; relied on available literature which may have publication bias toward positive findings; and could not assess unpublished forensic casework that might provide practical insights despite lacking formal publication.

CONCLUSION

Forensic odontology represents a dynamic and evolving field within dental science, with orthodontics playing an increasingly significant role. This systematic review confirms that orthodontic documentation through its comprehensiveness, detail, and temporal dimension provides invaluable resources for forensic identification. Dental records, palatal rugae patterns, bite marks (with appropriate caution regarding their reliability), lip prints, enamel rod patterns, photographs, and radiographs collectively contribute to establishing identity when other methods prove inadequate.

Orthodontists possess unique forensic potential through their extensive patient documentation practices. By maintaining meticulous records and collaborating with forensic specialists, they can significantly enhance victim identification in mass disasters, criminal investigations, and

missing person's cases. However, the field requires continued research to validate methodologies, establish standardized protocols, and address legal and ethical considerations.

As forensic science advances, orthodontists should recognize their potential contributions and seek appropriate training to participate effectively in this important interdisciplinary endeavor. With proper protocols and collaboration, orthodontic expertise will continue to strengthen forensic identification capabilities, ultimately serving justice and providing closure in challenging circumstances.

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Compliance with Ethical Standards

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