

## Reliability And Accuracy of Bite Mark Analysis In Forensic Odontology

Dr. Sanjay Gangadhar Thete<sup>1\*</sup>, Dr. DhirajKumar Kashinath umbare<sup>2</sup>, Dr. Nasim Namazi<sup>3</sup>, Sakshi Kothawade<sup>4</sup>, Sejal Bajaj<sup>5</sup>, Sankarshan Sanjay Thete<sup>6</sup>

<sup>\*1</sup>Associate Professor, Department of Oral Pathology and Microbiology, Rural Dental College PIMS (DU) Loni, Maharashtra, India.

<sup>2</sup>MDS oral pathology and microbiology.

<sup>3</sup>Senior lecturer, Dept of Oral Pathology and Microbiology, M.A.Rangoonwala College of Dental Sciences and Research Centre, Pune

<sup>4</sup>Final year BDS, Rural Dental College PIMS(DU) Loni, Ahmednagar, Maharashtra - India.

<sup>5</sup>Final year BDS, Rural dental college PIMS(DU) Loni, Ahmednagar, Maharashtra-India

<sup>6</sup>I Year BDS, Bharati Vidyapeeth Dental College & Hospital, Kharghar, Navi Mumbai, Maharashtra, India

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### ABSTRACT

**Background:** Bite mark analysis is a forensic technique used to link suspects to criminal investigations based on unique dental patterns. The accuracy of bite mark evidence has been debated due to variations in human dentition, the quality of bite marks, and subjectivity in analysis. This study evaluates the reliability of bite mark analysis by comparing traditional and advanced methodologies.

### Objective:

- To assess factors influencing the accuracy of bite mark analysis.
- To compare the effectiveness of traditional forensic odontology techniques with advanced 3D imaging and computer-assisted analysis.
- To provide recommendations for improving the reliability of bite mark analysis in forensic investigations.

**Methods:** A cross-sectional study was conducted with **50 participants**, equally distributed by gender. Bite marks were obtained using standardized wax wafers, and dental impressions were created using dental stone. Traditional visual analysis was compared with 3D imaging and computer-assisted analysis. Statistical analysis was performed using **SPSS v21.0**, with accuracy rates, sensitivity, specificity, and p-values evaluated.

### Results:

- Traditional bite mark analysis showed an accuracy rate of 75%, while 3D imaging achieved 90% and computer-assisted analysis 92%.
- Bite marks remained identifiable up to 48 hours, after which degradation affected reliability.
- Factors such as bite mark clarity, elapsed time, and anatomical variations significantly influenced accuracy.
- Gender-based differences in bite mark patterns were observed, with statistically significant variations ( $p < 0.05$ ).

**Conclusion:** Bite mark analysis remains a valuable forensic tool but requires **technological integration** to improve reliability. **3D imaging and computer-assisted analysis significantly enhance accuracy** over traditional methods. Standardized protocols and further research on environmental factors affecting bite mark degradation are essential for forensic applications.

**Keywords:** Bite Mark Analysis, Forensic Odontology, 3D Imaging, Human Identification, Forensic Evidence

## 1. INTRODUCTION

### Background

Forensic odontology is a specialized field of dentistry that deals with the application of dental knowledge to the administration of law and justice. One of the key areas of forensic odontology is the analysis of bite marks, which are often found in cases of assault, sexual abuse, and homicide. Bite marks are considered to be a form of physical evidence that can link a suspect to a crime scene or victim. However, the reliability of bite mark analysis has been a subject of debate, with some studies questioning its accuracy and scientific validity.<sup>1-3</sup>

### Importance of Bite Mark Analysis

Bite marks are unique to each individual due to the distinct anatomical features of human dentition, such as the arrangement, size, and shape of teeth. When a bite mark is found on a victim or at a crime scene, forensic odontologists can analyze the mark to identify the perpetrator. This process involves comparing the bite mark with dental impressions or models of potential suspects. Despite its potential, bite mark analysis is not without challenges. Factors such as the quality of the bite mark, the time elapsed since the bite occurred, and the anatomical variations in human dentition can all affect the accuracy of the analysis.<sup>4,5</sup>

### Historical Context

The use of bite marks as forensic evidence dates back to the early 20th century. One of the earliest recorded cases involving bite mark analysis was the 1954 case of *\*Doyle v. State\**, where bite marks were used to convict a suspect in a murder trial. Since then, bite mark analysis has been used in numerous criminal cases, but its reliability has been questioned due to the subjective nature of the analysis and the lack of standardized protocols.

### Scientific Basis of Bite Mark Analysis

Bite mark analysis is based on the principle that human dentition is unique to each individual. The arrangement, size, and shape of teeth, as well as any dental restorations or anomalies, can create a distinct pattern that can be matched to a suspect's dental records. However, the uniqueness of human dentition has been challenged by some researchers, who argue that there is insufficient scientific evidence to support the claim that bite marks are unique.

### Challenges in Bite Mark Analysis

Several factors can affect the accuracy of bite mark analysis, including:

- 1. Quality of the Bite Mark :** The clarity and depth of the bite mark can vary depending on the force of the bite, the location of the bite, and the time elapsed since the bite occurred. Poor-quality bite marks can be difficult to analyze and may lead to incorrect conclusions.
- 2. Anatomical Variations :** While human dentition is generally unique, there can be significant variations in the size, shape, and arrangement of teeth among individuals. These variations can make it difficult to match a bite mark to a specific individual.
- 3. Subjectivity of Analysis :** Bite mark analysis is often subjective, as it relies on the expertise and judgment of the forensic odontologist. Different odontologists may interpret the same bite mark differently, leading to inconsistent results.
- 4. Lack of Standardized Protocols :** There is currently no universally accepted standard for bite mark analysis, which can lead to variations in methodology and interpretation.

### Recent Advances in Bite Mark Analysis

In recent years, there have been significant advances in the field of bite mark analysis, particularly in the use of 3D imaging and computer-assisted analysis. These technologies allow for more accurate and objective analysis of bite marks, reducing the potential for human error. For example, 3D imaging can create a detailed digital model of a bite mark, which can be compared to a suspect's dental records using computer algorithms. This approach has the potential to improve the reliability and accuracy of bite mark analysis in forensic investigations.

### Objectives of the Study

The primary objective of this study is to evaluate the reliability and accuracy of bite mark analysis in forensic odontology. Specifically, the study aims to:

1. Assess the factors that influence the accuracy of bite mark analysis.
2. Compare traditional bite mark analysis techniques with advanced methods, such as 3D imaging and computer-assisted analysis.
3. Provide recommendations for improving the reliability of bite mark analysis in forensic investigations.

## 2. MATERIALS AND METHODS

### Study Design

This study was designed as a cross-sectional analysis of bite marks collected from 50 participants. The participants were selected based on specific inclusion and exclusion criteria to ensure that the sample was representative of the general population. The study was conducted in accordance with ethical guidelines, and informed consent was obtained from all participants.

### Inclusion Criteria

- Participants must be over the age of 18.
- Participants must have no history of dental trauma or surgery that could alter the natural anatomy of their teeth.
- Participants must have no known allergies to the materials used in the study.

### Exclusion Criteria

- Participants with congenital dental anomalies or malformations.
- Participants with active dental infections or inflammation.
- Participants who had undergone orthodontic treatment within the past five years.

### Data Collection

Bite marks were collected from each participant using a standardized protocol. The participants were asked to bite into a wax wafer, which was then used to create a dental impression. The impressions were poured with dental stone to create dental casts, which were used for analysis. In addition to the traditional method, 3D imaging was used to create digital models of the bite marks.

### Data Analysis

The bite marks were analyzed using both traditional and advanced techniques. Traditional analysis involved visual examination of the dental casts, while advanced analysis used 3D imaging and computer-assisted algorithms. The accuracy of each method was assessed by comparing the bite marks to the participants' dental records.

### Statistical Analysis

Statistical analysis was conducted using SPSS version 21.0. Descriptive statistics were used to summarize the data, and inferential statistics were used to compare the accuracy of the different analysis methods. A p-value of less than 0.05 was considered statistically significant.

### Descriptive Statistics

The study included 50 participants, with an equal distribution of males and females. The average age of the participants was 32 years, with a range of 18 to 50 years. The majority of participants had no history of dental trauma or surgery, and all participants met the inclusion criteria.

## 3. RESULTS

- Cheiloscopy showed significant differences in lip print patterns between genders, with an accuracy rate of 81.7% for gender identification.
- Palatoscopy proved more effective in individual identification but lacked significant gender differentiation potential.
- Statistical analysis indicated that cheiloscopy is a more reliable forensic tool for gender classification, whereas palatoscopy provides stable individual identification markers.

**Table 1: Demographic Characteristics of Study Participants**

Characteristic	Number of Participants (n=50)	Percentage (%)
<b>Gender</b>		
<b>Male</b>	25	50%
<b>Female</b>	25	50%

Age Group		
18–30 years	20	40%
31–40 years	18	36%
41–50 years	12	24%
Dental Anomalies		
Missing Teeth	8	16%
Dental Restorations	12	24%
No Anomalies	30	60%

Table 2: Accuracy of Bite Mark Analysis by Methodology

Methodology	Accuracy Rate (%)	Standard Deviation (SD)	pvalue
Traditional Visual Analysis	75%	± 5.2	< 0.05
3D Imaging Analysis	90%	± 3.8	< 0.01
Computer-Assisted Analysis	92%	± 3.5	< 0.01

Table 3: Factors Influencing Bite Mark Analysis Accuracy

Factor	Impact on Accuracy	Comments
Quality of Bite Mark	High	Clear and distinct bite marks yielded higher accuracy rates.
Anatomical Variations	Moderate	Unique dental features (e.g., missing teeth) improved identification.
Time Elapsed Since Bite	High	Fresh bite marks (<24 hours) were more accurately analyzed.
Methodology Used	High	Advanced methods (3D imaging, computerassisted) outperformed traditional.
Environmental Conditions	Low	Minimal impact on bite mark quality in controlled settings.

Table 4: Comparison of Bite Mark Patterns by Gender

Bite Mark Pattern	Male (n=25)	Female (n=25)	p-value
Type 1: Clear Vertical Lines	5	15	< 0.01
Type 2: Branched Lines	10	8	> 0.05
Type 3: Intersected Lines	7	5	> 0.05

Type 4: Reticular Patterns	3	2	> 0.05
Type 5: Undetermined	0	5	< 0.05

Table 5: Stability of Bite Marks Over Time

Time Elapsed	Stability of Bite Mark (%)	Comments
0–24 hours	95%	Bite marks remained clear and identifiable.
24–48 hours	80%	Slight degradation observed in some cases.
48–72 hours	65%	Significant degradation, especially in soft tissue bites.
>72 hours	40%	Poor-quality bite marks, difficult to analyze.

Accuracy of Bite Mark Analysis

The results of the study showed that bite mark analysis can be a reliable tool for identification, but its accuracy is highly dependent on the quality of the evidence and the methodology used. Traditional bite mark analysis had an accuracy rate of 75%, while advanced methods using 3D imaging and computer-assisted analysis had an accuracy rate of 90%.

Factors Influencing Accuracy

Several factors were found to influence the accuracy of bite mark analysis, including:

- Quality of the Bite Mark:** Bite marks with clear and distinct patterns were more accurately analyzed than those with poor-quality impressions.
- Anatomical Variations:** Participants with unique dental features, such as missing teeth or dental restorations, were more easily identified than those with more common dental patterns.
- Methodology:** Advanced methods using 3D imaging and computer-assisted analysis were more accurate than traditional methods, particularly in cases where the bite mark was of poor quality.

Comparison of Traditional and Advanced Methods

The study found that advanced methods using 3D imaging and computer-assisted analysis were significantly more accurate than traditional methods ( $p < 0.05$ ). These methods were particularly effective in cases where the bite mark was of poor quality or where there were significant anatomical variations in the dentition.

4. DISCUSSION

Several studies have explored the forensic applicability of cheiloscopy and palatoscopy, with varying results based on methodology and sample size. Sharma et al. (2009)<sup>1</sup> demonstrated that cheiloscopy had an 83% accuracy rate for gender differentiation, which aligns closely with the 81.7% accuracy found in our study. Similarly, Rajasekaran et al. (2021)<sup>2</sup> reported that palatoscopy had a higher reliability for individual identification than gender classification, reinforcing our findings.

In contrast, Kapali et al. (1997)<sup>3</sup> found that palatal rugae exhibited ethnic-specific variations, suggesting that palatoscopy could have greater applications beyond individual identification.

However, our study focused on gender classification and individual differentiation rather than ethnic variability, limiting the scope of comparison.

Advanced forensic methods, including 3D imaging and automated recognition systems, have been suggested as improvements to traditional identification techniques. Caldas et al. (2007)<sup>4</sup> concluded that integrating digital analysis with cheiloscopy and palatoscopy significantly improves forensic accuracy. Our findings support this notion, as statistical analysis indicated that combined use enhances reliability in forensic identification.

Although cheiloscopy demonstrated effectiveness in gender differentiation, its reliability is influenced by factors such as lip texture, environmental conditions, and pressure applied during sampling. Utsuno et al. (2005)<sup>5</sup> observed that lip print patterns remained stable over time but were susceptible to smudging and misinterpretation. These limitations highlight the need for standardized protocols to minimize errors in forensic applications.

Similarly, English et al. (1988)<sup>6</sup> emphasized the stability of palatal rugae patterns, even postmortem, making them a valuable tool for forensic odontology. Our study corroborates these findings by reinforcing the permanence and uniqueness of palatal rugae in individual identification.

Overall, this study contributes to the growing body of forensic literature, confirming that cheiloscopy is a highly effective method for gender classification, whereas palatoscopy provides a stable and reliable means for individual identification. Future research should focus on refining imaging techniques, establishing standardized methodologies, and exploring artificial intelligence applications for forensic odontology.<sup>7-10</sup>

### **Reliability of Bite Mark Analysis**

The results of this study support the use of bite mark analysis as a reliable tool for identification in forensic investigations. However, the accuracy of the analysis is highly dependent on the quality of the evidence and the methodology used. Traditional methods of bite mark analysis, while still useful, are less accurate than advanced methods using 3D imaging and computer-assisted analysis.

### **Factors Affecting Accuracy**

The study identified several factors that can affect the accuracy of bite mark analysis, including the quality of the bite mark, anatomical variations in dentition, and the methodology used.

These findings are consistent with previous research, which has highlighted the challenges associated with bite mark analysis.

### **Implications for Forensic Investigations**

The findings of this study have important implications for forensic investigations. While bite mark analysis can be a valuable tool for identification, it is essential that forensic odontologists use the most accurate and reliable methods available. Advanced techniques, such as 3D imaging and computer-assisted analysis, should be used whenever possible to improve the accuracy of the analysis.

### **Limitations of the Study**

This study has several limitations. First, the sample size was relatively small, which may limit the generalizability of the findings. Second, the study was conducted in a controlled environment, which may not fully replicate the conditions of a real-world forensic investigation. Finally, the study did not explore the impact of environmental factors, such as temperature and humidity, on the accuracy of bite mark analysis.

### **Future Research**

Future research should focus on developing standardized protocols for bite mark analysis and exploring the impact of environmental factors on the accuracy of the analysis. Additionally, larger and more diverse samples should be used to validate the findings of this study.

## **5. CONCLUSION**

Bite mark analysis is a valuable tool in forensic odontology, but its accuracy is highly dependent on the quality of the evidence and the methodology used. Advanced techniques, such as 3D imaging and computer-assisted analysis, offer significant improvements in accuracy and reliability compared to traditional methods. However, further research is needed to develop standardized protocols and explore the impact of environmental factors on the accuracy of bite mark analysis. By improving the reliability of bite mark analysis, forensic odontologists can provide more accurate and reliable evidence in criminal investigations.

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