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Comparative Analysis of Bite Mark Accuracy on Food Substances: A Forensic Investigation

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Abstract

Background: Bite marks on food substances may preserve characteristic features of an individual's dentition. Their forensic usefulness, however, depends on substrate stability and the analytical method used for comparison.

Materials and Methods: Twenty-five healthy adults produced bite marks on apple, cheese, and chocolate, generating 75 physical samples. Bite marks were reproduced using polyvinyl siloxane impressions and Type IV dental stone. Each evidence cast was compared with five suspect casts—one true match and four distractors—using manual docking and computer-assisted overlay analysis in Adobe Photoshop CC 2021. Correct and incorrect identifications were recorded.

Results: Computer-assisted overlay showed higher overall observed accuracy than manual docking (82.7% vs. 70.7%) and a lower error rate (17.3% vs. 29.3%). Manual docking was most accurate for cheese (92.0%), whereas computer-assisted overlay was most accurate for

chocolate (96.0%). Apple demonstrated the lowest accuracy with both methods. The overall difference between methods was not statistically significant (χ^2 = 2.385, p = 0.122).

Conclusion: Computer-assisted overlay showed a higher observed accuracy, particularly for chocolate, while cheese provided the most consistent performance. Bite mark comparison should remain cautious and substrate-specific and requires further validation with larger samples, multiple examiners, and three-dimensional imaging.

Keywords: forensic odontology; bite mark analysis; food substrates; manual docking; computer-assisted overlay; apple; cheese; chocolate.

Introduction

Forensic odontology contributes to human identification, age estimation, analysis of dental injuries, and examination of patterned injuries such as bite marks. Teeth are durable structures, and their morphology, alignment, spacing, restorations, and wear patterns may provide useful information in forensic investigations.[1,2-4]

A bite mark is a pattern produced by teeth on a substrate during a biting incident. The traditional premise of bite mark comparison is that features of the dentition may be transferred to a substrate and compared with a suspect's dental structures. Relevant features include tooth alignment, spacing, rotations, fractures, and wear facets.[1,5,6]

Food substances provide controlled, non-living substrates for experimental bite mark research. Apple, cheese, and chocolate differ in moisture, elasticity, plasticity, brittleness, and susceptibility to temperature-related changes. These properties can influence the clarity and dimensional stability of the recorded pattern.[1,7-9]

Manual docking involves physically articulating dental casts with a bite-mark replica. Computer-assisted overlay involves tracing the incisal or occlusal edges of a suspect cast and superimposing the outline on a calibrated image of the evidence cast. Digital comparison may improve documentation and permit controlled adjustment of scale, rotation, and transparency.[1,5]

Despite technological advances, bite mark analysis remains affected by subjectivity, distortion, lack of standardization, and uncertainty regarding error rates.[4,6,10,11,12] The present study therefore compared manual docking and computer-assisted overlay across three food substrates under controlled experimental conditions.

Aim And Objectives

The aim was to evaluate and compare the accuracy of bite mark analysis on apple, cheese, and chocolate using manual docking and computer-assisted overlay techniques.

- To quantitatively assess the accuracy of matching dental casts with bite-mark evidence casts.
- To compare apple, cheese, and chocolate as substrates for recording identifiable bite mark patterns.
- To evaluate the accuracy and consistency of manual docking versus computer-assisted overlay.
- To assess the relationship between substrate type and analytical method.

Materials and Methods

Study design and setting

This in vitro experimental comparative study was conducted in the Department of Oral Medicine, Diagnosis and Radiology, Rungta College of Dental Sciences and Research, Bhilai, Chhattisgarh. A repeated-measures design was used, allowing each

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participant to serve as their own control. Ethical approval was obtained from the Institutional Ethics Committee (Ref. No. RCDSR/IEC/MDS/2023/, dated 03/04/2024), and written informed consent was obtained from all participants.

Sample size and participants

The minimum sample size calculated using G*Power was nine participants. The sample was increased to 25 participants to improve robustness and account for possible dropouts. Each participant produced one bite mark on each substrate, resulting in 75 physical samples: 25 apple, 25 cheese, and 25 chocolate. Because each sample was analyzed by two methods, 150 method-wise observations were generated.

Food substrates and materials

Fresh, firm apples of uniform size, a standardized firm processed cheese block, and a standardized solid dark chocolate bar were used. Cheese and chocolate were stored at 4–8°C and allowed to equilibrate to room temperature before use.

Experimental procedure

Suspect cast fabrication: Maxillary and mandibular impressions were made using chromatic alginate. The impressions were disinfected, rinsed, and poured with Type IV dental stone. Casts were trimmed, finished, and assigned unique codes.

Bite mark generation: Cheese and chocolate were cut into standardized blocks, whereas apples were presented whole. Participants were instructed to deliver one firm vertical bite without lateral, tearing, or scraping movements. The order of substrates was randomized. Samples were labeled and refrigerated at 4–8°C within one hour.

Evidence cast fabrication: Within 24 hours, bite marks were impressed using a two-step polyvinyl siloxane technique. Light-body material was applied to the indentations and supported with heavy-body material. The impressions were poured with Type IV dental stone to create positive evidence casts.

Bite mark analysis

A single calibrated examiner, blinded to cast identity, compared each evidence cast with five suspect casts comprising one true match and four randomly selected non-matching distractors. Each comparison was scored as correct or incorrect.

Manual docking: Suspect casts were physically articulated into the indentations of the evidence cast. The examiner assessed three-dimensional congruence, tooth alignment, rotations, spacing, fractures, and wear facets.

Computer-assisted overlay: High-resolution photographs were obtained with an ABFO No. 2 scale in the same plane as the cast. The camera was positioned perpendicular to the surface. Incisal and occlusal edges were traced in Adobe Photoshop CC 2021, scaled to 1:1, and superimposed on the evidence-cast image. Position, rotation, and transparency were adjusted to assess concordance.

Results

Overall accuracy

Analytical method	Correct	Incorrect	Observed accuracy	Error rate
Manual docking	53/75	22/75	70.7%	29.3%
Computer-assisted overlay	62/75	13/75	82.7%	17.3%
Total	115/150	35/150	76.7%	23.3%

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Computer-assisted overlay demonstrated a 12-percentage-point increase in observed overall accuracy compared with manual docking.

Substrate-wise accuracy

Food substrate	Manual docking	Computer-assisted overlay
Apple	11/25 (44.0%)	16/25 (64.0%)
Cheese	23/25 (92.0%)	22/25 (88.0%)
Chocolate	19/25 (76.0%)	24/25 (96.0%)

Manual docking was most accurate for cheese, whereas computer-assisted overlay was most accurate for chocolate. Apple showed the lowest accuracy with both methods.

Statistical comparison

The overall difference between manual docking and computer-assisted overlay was not statistically significant ($\chi^2 = 2.385$, $p = 0.122$). The numerical difference should therefore be interpreted as an observed trend rather than evidence of definitive superiority.

Discussion

The present study demonstrates that both substrate characteristics and analytical method may influence bite mark comparison accuracy. Computer-assisted overlay achieved higher observed overall accuracy than manual docking, possibly because calibrated images, adjustable transparency, controlled superimposition, and a permanent digital record can reduce some sources of subjectivity.[1,5,12,]

Apple demonstrated the lowest accuracy with both methods. Its fibrous texture, high moisture content, dehydration, browning, and susceptibility to dimensional change may compromise the clarity and stability of the bite pattern.[1,7] Although computer-assisted overlay improved accuracy from 44.0% to 64.0%, apple remained the most challenging substrate in the present study.

Cheese showed the highest manual-docking accuracy (92.0%) and consistent overall performance. Its plasticity may allow it to retain three-dimensional tooth impressions without substantial elastic recoil.[1,8.] The small advantage of manual docking in this study may reflect the usefulness of direct three-dimensional assessment when the impression is well preserved.

Chocolate showed the highest computer-assisted overlay accuracy (96.0%). Its ability to preserve fine details, combined with digital superimposition, may have contributed to the observed performance.[1,9] However, chocolate is sensitive to heat-related softening and requires controlled storage and handling.[7,9]

The findings are consistent with previous research reporting better preservation of bite marks in cheese and chocolate than in apple and emphasizing the potential value of digital and three-dimensional methods.[1,3,9,12] Nevertheless, current evidence does not support generalized claims of definitive individual identification from bite marks, particularly when substrate distortion, methodological limitations, and examiner subjectivity are considered.[4,6,11]

Limitations

- The in vitro design may not represent the full variability of actual forensic casework.
- The sample size was limited to 25 participants.
- Only one calibrated examiner performed the comparisons, preventing assessment of inter-examiner variability.

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- The computer method used two-dimensional overlay rather than advanced three-dimensional imaging.
- Food substrates may vary in composition, texture, ripeness, brand, and temperature.
- The findings should not be generalized to bite marks on human skin or interpreted as definitive individual identification.

Conclusion

Within the limitations of this investigation, computer-assisted overlay demonstrated higher observed overall accuracy than manual docking for bite mark comparison on food substrates (82.7% vs. 70.7%). Chocolate performed best with computer-assisted overlay, whereas cheese showed consistent performance across methods. Apple was the least reliable substrate. The study supports a cautious, substrate-specific, evidence-based approach and recommends further research using larger samples, multiple blinded examiners, and advanced three-dimensional imaging workflows.[4-7,11,12]

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Legend Figures



Figure 1: Apple



Figure 2: Chocolate



Figure 3: Cheese



Figure 4: Impression and Casting materials



Figure 5: Armamentarium used in the study. (a) Instruments and materials used for collection and handling of bite mark samples, including kidney tray, storage bags, labeling marker, gloves, and protective equipment. (b) Digital camera (Canon EOS) (c) ABFO No. 2 scale



Figure 6: Showing the methodology to obtain positive replica of bitten surface on apple

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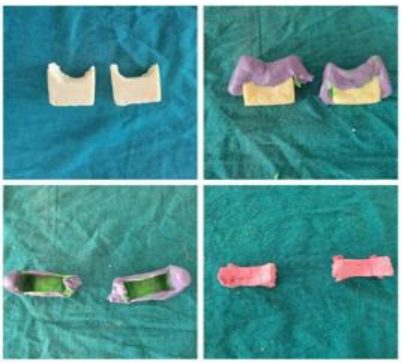


Figure 7: Showing the methodology to obtain positive replica of bitten surface on cheese



Figure 8: Showing the methodology to obtain positive replica of bitten surface on chocolate



Figure 9(a):

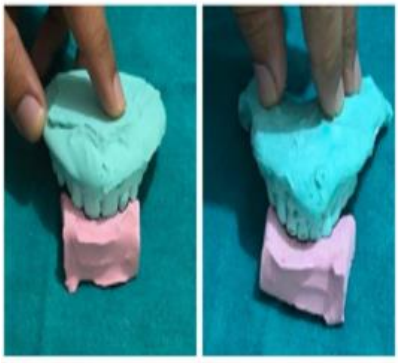


Figure 9(b):



Figure 9 (c):

Figure 9. Manual docking analysis of bite mark patterns on apple (a) cheese (b) and chocolate (c), reproduced as die stone casts and compared with maxillary and mandibular casts of subject 1

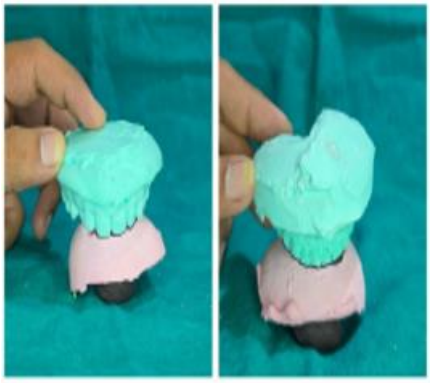


Figure 10(a):



Figure 10(b):

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Figure 10(c):

Figure 10: Manual docking analysis of bite mark patterns on apple (a) cheese (b) and chocolate (c), reproduced as die stone casts and compared with maxillary and mandibular casts of subject 2



Figure 11: Showing selection of incisal edges using the "magic wand" wizard tool in Adobe Photoshop software from the photograph of dental cast and the superimposition of computer generated overlays over the photograph of bite mark on apple, cheese and chocolate done to check for matching of subject 1

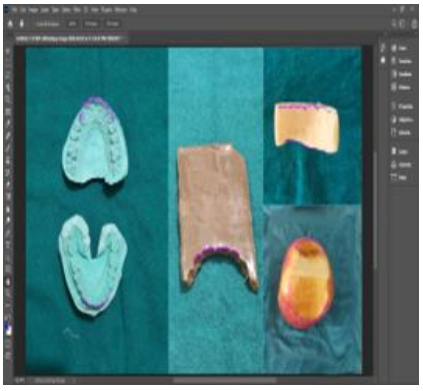


Figure 12: Showing selection of incisal edges using the "magic wand" wizard tool in Adobe Photoshop software from the photograph of dental cast and the superimposition of computer generated overlays over the photograph of bite mark on apple, cheese and chocolate done to check for matching of subject 2.

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