Bite Marks: Indispensable Forensic Evidence

G R K N V Subbarao[1], A. Naga Supriya[1], Ravikanth Manyam[1], Swetha P[1], Smita Birajdar[1], Kranti Kiran Reddy Ealla[2]

ABSTRACT

Introduction: Forensic odontology involves the collection, management, interpretation, evaluation, and presentation of dental evidence for criminal or civil legal proceedings, a combination of various aspects of the dental, scientific and legal professions. Bite mark analysis is an essential aspect of it that can significantly impact the courtroom or when considering the care of children and women deemed at risk.

Materials and Methods: Data were obtained and analyzed from previously published literature and electronic database searches of relevant published literature from PubMed and Google Scholar. Forensic odontologists examine, interpret, analyze, and prepare reports on bruises or marks thought to be caused by teeth and, on occasion, are cross-examined in a court of law. Hence, they are considered essential in forensic dentistry in solving crimes to find either suspects or even victims in self-inflicted injuries as they are caused either by humans or animals that reveal biting edges, spacing, restorations, missing teeth, broken teeth, or supernumerary teeth unique to that individual. The main reasons for causation are sexual crimes, homicides, child abuse, and violent fights. There are many methods to analyze, that are classified into manual, semi-automatic, and automatic methods.

Objectives: This review highlights the bite marks in detail about their characteristics, methods of collection and different methods of analysis and its applications in forensic odontology.

Conclusion: This review shows different methods of analyzing bitemarks and explains the advantages, disadvantages, and limitations, and identifies which method is better advisable and adaptableforanalysis.

Keywords: Bite marks, Digital approaches, Manual approaches, Overlays, Softwares.

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INTRODUCTION

Modern society is advanced in all aspects including violence and acts of crime. The faculty of criminal investigations have reached the height of its efficiency which involves distinct disciplines in order to solve the crime. It is pride that human dentition is quite frequently coming to rescue to address the requirements in the identification of degraded/ fragmented residue of the human body based on hard tissue as a substitute for fingerprints. In the said process teeth and bones are also used as the best source of DNA which plays a key role in the identification process. The landmark growth of technology and science have proved useful to identify blood group of human beings through teeth which drastically narrowed down the large group of suspects. In fact, the dentition status of a person is very much useful in the estimation of age and in the identification of a dead body especially in mass disasters that render large-scale crime scenes. The branch of forensics dealing with bite marks collected in cases concerning child abuse, neglect, murders, and rapes have yielded sound results which ultimately helped a lot in the process of conviction of culprits.

The word Forensic is derived from the Latin word "forum" for the public, it describes the science of associating people, places, and things involved in criminal activities. It is self-explanatory that it applies to public or legal issues and their analysis to find out legal requirements based on reports and evidence.

[1]Department of Oral Pathology, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India; [2]Department of Oral Pathology, Malla Reddy Institute of Dental Sciences, Hyderabad, Telangana.

Corresponding Author: G R K N V Subbarao, Department of Oral Pathology, Vishnu Dental College, Mail id: subbughanta1919@gmail.com, Bhimavaram, Andhra Pradesh, India. E-mail Id: .

After much endeavor in the form of tremendous efforts in this field, forensic odontology started playing a vital role in labelling the offense with culprits and victims by assessing several additional aspects and deals with examining dental evidence, evaluating, and presenting dental findings in the interest of justice by using previous dental records, radiographs, photographs, tooth prints, DNA fingerprinting, rugoscopy, and chelioscopy[1]. Bite marks in forensic odontology also play a significant role in finding either suspects or victims in legal proceedings.[2] This review highlights the bite marks in detail about their characteristics, methods of collection and different methods of analysis and its applications in forensic odontology.

MATERIALS AND METHODS

Data were obtained and analyzed from previously published literature and electronic database searches of relevant published literature from PubMed and Google Scholar.

HISTORY

The first incident of bite mark identification occurred during 1692 which was termed as Salem Witch Trials. A bite mark on a piece of cheese found at the scene of a robbery helped to disclose the thief's identity and so solve the case in America. The case involving serial killer Theodore (Ted) Bundy was the most well-known bite mark case that paved the way for bite mark evidence to be utilized in courts., who was convicted based on bite mark analysis by the US judicial system[3,4].

DEFINITION:

Bite marks are defined as "the marks caused by the teeth either alone or in combination with other mouthparts"[3]. The main reasons for their formation are homicides, sexual crimes, child abuse, violent fights, sports-related fights, animal encounters, burglaries (bite marks left on food items)[4]. Generally, they reveal tooth ridges of biting surfaces, tooth spacings, restorations, missing tooth, chipped tooth, distorted tooth, supernumerary tooth, malposition tooth. The reliability depends on the behavioral aspect of the skin and underlying tissues; it is resilient due to viscoelasticity, anisotropic, and its nonlinear response to stresses like biting forces[5].

Classifications of Bite Marks[6]:

1. Cameron's classification (Rao et al. 2016):
   • The agents that produced the mark- Humans, Animals.
   • The materials and substances that have exhibited the marks- Skin, body tissues, foodstuff.

2. McDonald's classification:
   • Tooth pressure marks:
   ➢ By incisal edges of anterior teeth – stable with minimal distortion
   • Tongue pressure marks:
   ➢ Tongue pressure on palatal surfaces of the teeth, cingulae or palatal rugae distorts marks.
   • Tooth scrape marks:
   ➢ Caused due to irregularities in teeth due to fractures, restorations, etc.
   • Complex marks:
   ➢ Combination of above marks.

3. Websters classification:
   • Type I:
   ➢ Bites in chocolate fracture easily with a limited depth of penetration. Most prominent is the incisal edges of the upper and lower anterior teeth.
   • Type II:
   ➢ Good grip of material obtained by teeth and then bitten piece is fractured from main material.
   Example: Apple; The outline of labial aspect of upper and lower incisors are recorded.
   • Type III:
   ➢ Bite mark produced by biting through cheese. Here, an advantage is that it indicates the relative position of upper and lower incisors in centric occlusion.

4. Clinical classification (Gustafson in 1996):
   1) Sadistic or sexual bite
   2) Aggressive bite
   3) Most aggressive bite involves ears, nose, and nipples.

5. By degree of impression (Shashikala K 2003):
   1) Hemorrhage- a small bleeding spot
   2) Abrasion- undamaging mark on the skin
   3) Contusion- ruptured blood vessels, bruise
   4) Laceration- near puncture of the skin
   5) Incision- neat punctured or torn skin
   6) Avulsion- removal of skin
   7) Artifact- bitten- off a piece of body

6. Agents producing marks (Masthan 2009):
   1) Humans- adults, children
   2) Animals- mammals, reptiles, fish
   3) Mechanical- dentures, saw blades

7. Materials in which bite marks are produced (Masthan 2009):
   1) Skin and bony tissues
   2) Food substances
   3) Materials chewed habitually e.g., Pipe stems, pens, and pencils

8. Other classification (Masthan 2009):
   1) Sexually oriented bites
   2) Child abuse cases
   3) Self-inflicted marks

Characteristics:

Bite marks are a distinct double horse-shoe pattern of anterior teeth of both maxillary and mandibular arches, and rarely posterior teeth are observed caused by either humans or animals. Mandibular anterior teeth are detected more obviously than the maxillary teeth in bite marks, which is owed to jaw movement during bite infliction. They are produced due to teeth pressure and start with mandibular closure, followed by suction on the skin (as a negative pressure up to 20 mmHg). Tongue thrusts can accompany the opposite action of the mandible which are seen as tongue projections on teeth incisor and lingual surfaces. The maximum pressure exerted by the incisors along with the tongue is about 11 kg pressure and it may reach up to 8 lbs./square inches[7].

Bite marks can be identified using gross and, individual

characteristics, and site of bite mark injury given by Sweet[8]. Bite marks appear as circular or elliptical on the skin with the central area of ecchymosis due to tongue suckling action. Class characteristics are unique outline forms to each set of teeth like Incisors have a rectangular shape, Canine have triangular form, Premolar and Molar have spherical or pointed shapes. Individual characteristics are fractures, rotations, spacings, malposed tooth, supernumerary tooth, and retained deciduous tooth unique to their dentitions[9].

The injury site differs for males and females and males are affected in areas of genitals, arms, shoulders, and fingers, and females are most commonly affected in the regions of the breast, legs, and inner parts of the thigh[4]. Depending on the intensity of the bite, there may be laceration injury (break-in surface integrity), and if there are extreme biting forces, Avulsion injury (part of the tissue is bitten off) takes place at the site of injury[10].

Evidence Collection[11]:

From Questioned Patterns, Patterned Injuries, Bitemarks, Persons of Interest, and Dentitions.

Evidence of collection from questioned bitemarks

i. General considerations:

The collecting of first evidence from a questioned bitemark can be a one-time event with no chance of a follow-up inspection. When the odontologist is involved in the initial examination, the collection of evidence from the site(s) should include the methods of documentation described below. Evidence that was collected by others may be provided. Odontologists should evaluate such evidence and proceed only if the evidence's forensic importance or evidential value warrants further investigation.

Legal permission in the form of written consent, search warrant, or court order should be obtained from the appropriate authority before investigative procedures and should be noted in the reports.

ii. Documentation

    a. General description:
        Case number
        Examiner
        Age, sex, and race of bitemark recipient

    b. Pattern location
        Anatomical location of patterned injuries
        Surface contour
        Tissue characteristics
        Object (medium) description, if not human skin

    c. Pattern or injury features
        Size
        Shape
        Nature (abrasion, contusion, laceration, avulsion)
        Other (indentations, incisions, unusual features)

    d. Pattern description
        Orientation of maxillary/mandibular dental arches
        Locations of midlines
        Individual tooth marks
        Unmarked areas
        Tooth rotations, translations, or anomalies
        Summary

iii. Orientation photographs:

Before other evidence collection procedures, orientation images should be exposed to document the identity of the object or person, case information, and demonstrate the location(s) of the questioned bitemarks.

When possible, a high-quality digital camera should be used to image the pattern or patterned injury, which should be done by or under the direction of the forensic odontologist.

Once the orientation images have been exposed as recommended in progressively closer, photographs should be sequentially exposed of each questioned bitemark without and with a properly placed and labeled reference scale (e.g., ABFO No.2© or similar). Images should be of sufficient resolution to allow for enlargement to a life-sized dimension without pixelation.

In some cases, it can be beneficial to obtain serial photographs of the patterned injury over time. Both ambient and artificial lighting can be used, as well as infrared (IR), reflective ultraviolet (UVA), and alternate light source (ALS) imaging when indicated.

iv. Swabbing:

Due care is required to be taken while swabbing the questioned bite mark for clinical evidence strictly adhering to norms of the legal fraternity. The motive of making such swabs is to collect saliva which would have been present on the body of a person while biting or sucking and it will be analysed for the collection of cells to locate DNA, the ultimate ingredient in the process of identification. The amount of saliva deposited with a bite mark is approximately 0.3ml, which is dispersed over a 20 cm wide area. Swabs should be taken as soon as possible after the bite and before the bitten site is cleansed or washed. If it is determined that the bite was caused by clothing, efforts should be made to confiscate the clothing for DNA testing.

The following technique will maximize the amount of DNA recovered. First, a cotton swab moistened with distilled water is employed to wash the surface that was contacted by the tongue and lips using light pressure and circular motions to wash the dried saliva from the surface for 7 to 10 seconds. Then, a second dry swab is used to collect the remaining moisture that is left on the skin by the first swab. Before being released to police authorities for testing, both swabs are thoroughly air-dried at room temperature for at least 45 minutes. The two swabs must be kept cool and dry to reduce the degradation of salivary DNA evidence and the growth of bacteria that may contaminate.

Swabs are bundled and submitted to the laboratory after drying. A control sample is prepared using the same method but without swabbing the saliva. Using absorption-elution or absorption-inhibition group testing, saliva obtained through swabbing is used to determine blood group antigens. The activity of saliva's amylase in hydrolyzing a starch substrate is used to identify it. In case of sexual assault, oral swabs should also be taken for semen. Mouthwashes (with water) can be used to gather spermatozoa test samples[12].

v. Impressions

Impressions should be taken of the surface containing questioned bitemarks, especially when three-dimensional properties are present. The imprint materials used should match

American Dental Association (ADA) criteria and be listed by name in the report, along with the lot number and expiration date.

Impressions should be taken from the person with a questioned bitemark to assess the possibility of a self-inflicted bitemark. Or, in case the person may have bitten another person that was involved in the incident.

**Evidence collection from persons of interest:**

i. General Considerations

The odontologist should get a formal search warrant, court order, or other legal consent from the competent authorities, or the subject person in the case of informed consent, before collecting evidence from persons of interest. Copies of these documents should be retained as part of the case record.

Whenever practical, the odontologist who collects the evidence from a questioned bitemark should not also collect evidence from the dentitions of persons of interest. There is an exemption if the odontologist believes that a bitemark in question was self-inflicted. In these cases, the odontologist should also collect evidence from that person's dentition.

A second odontologist or another dentist should collect evidence from persons of interest whenever possible, following the principles below. If only one person of interest is preferred, to produce a dental line-up a second odontologist another dentist should collect evidence from persons of interest following the guidelines below. If only one person of interest is preferred, to
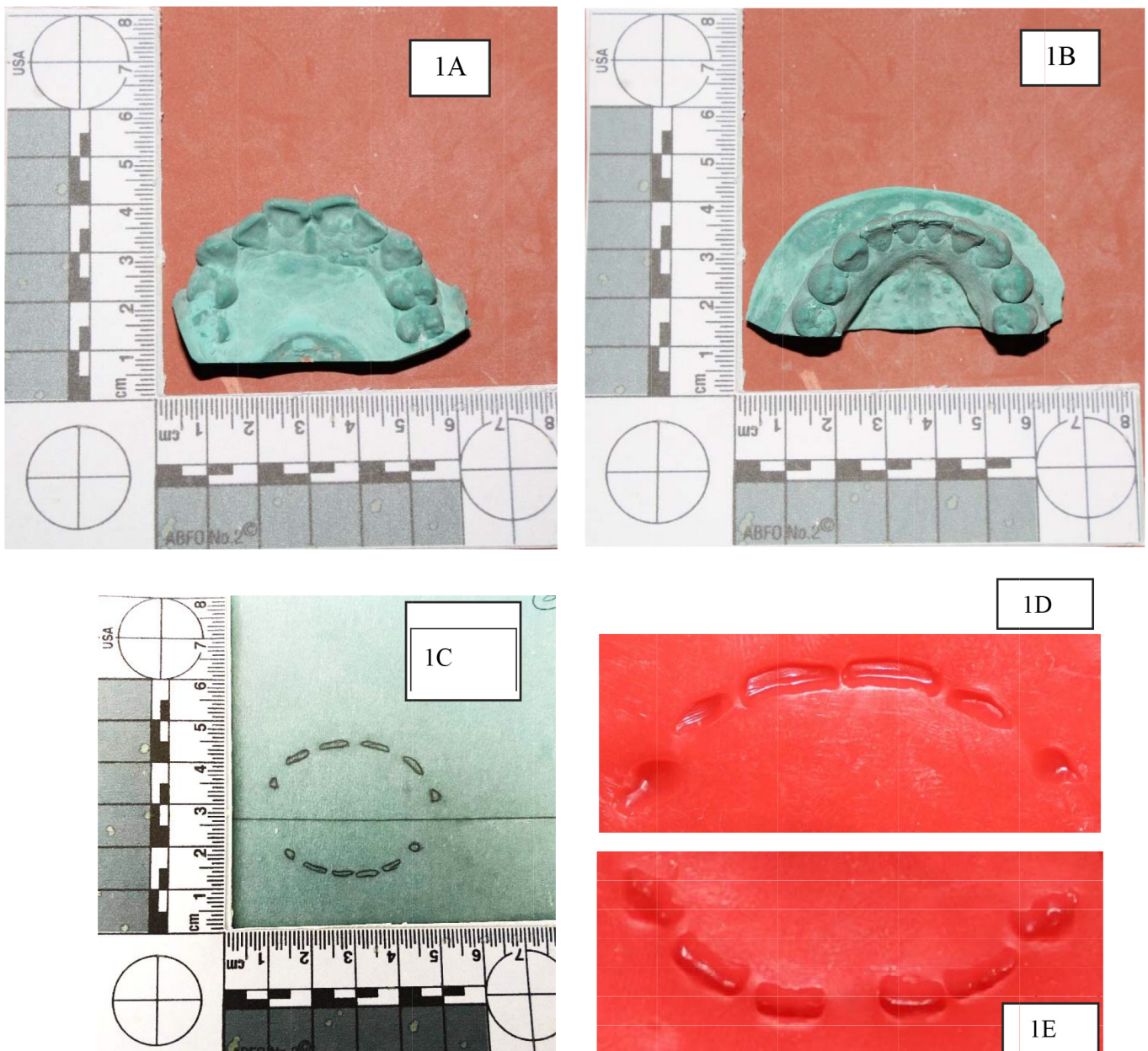
Figs. 1: A) & B) Maxillary and mandibular model casts with ABFO no:2 reference scale; **C)** Hand tracing on acetate sheets; **D)** & E) Maxillary and mandibular wax impressions by Type-2 Modelling wax for manual methods.

produce a dental line-up a second odontologist or dentist should collect or provide evidence from other individuals who are foils with similar dentitions to the person of interest.

ii. Evidence collected should include:
　　Demographic and other identifying information
　　Dental treatment records, if available

iv. Photography

To the extent possible, photographic documentation should include:
　　　　Extraoral photographs
　　　　Full face
　　　　Right and left three-quarter profiles
　　　　Right and left full profiles
　　Intraoral photographs (with retractors and mirrors as needed):
　　　　Anterior view with teeth closed

　　　　Anterior view with teeth slightly parted
　　　　Anterior view with mandible protruded
　　　　Anterior view demonstrating the maximal opening
　　with a reference scale or without reference scale:
　　　　Lateral views, both left, and right sides
　　　　Occlusal views of each arch
　　　　Additional photographs that may provide useful information
　　　　Images of surfaces of test bites with and without reference scales
　　　　Video imaging can be used in addition to conventional still photography

v. Intraoral examination

The dentist performing the intraoral examination should document the condition of the teeth, including the following:
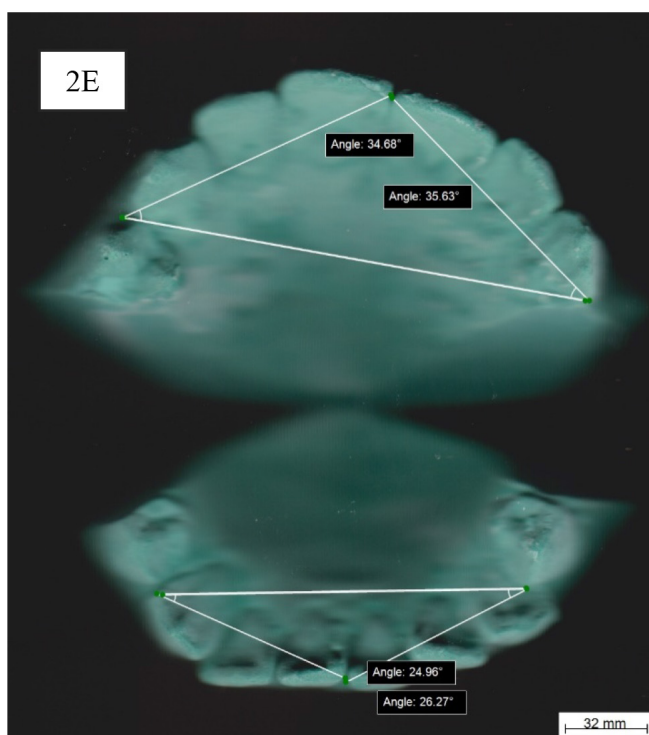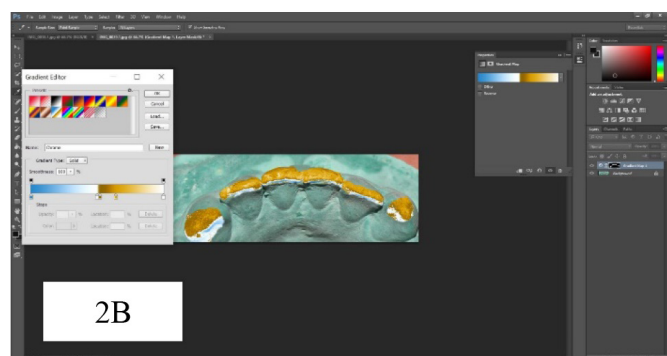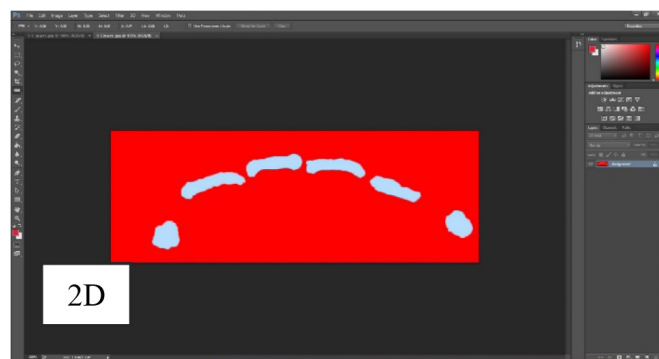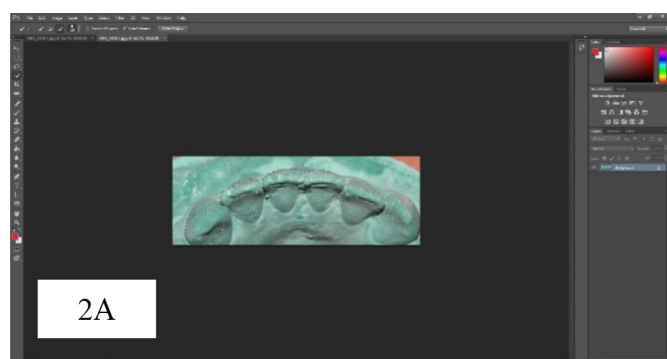

Fig. 2: A) Mandibular model cast uploaded in photoshop 2014 cc version for overlay generation; **B)** Gradient selection of biting edges by quick selection tool; **C) & D)** Using selected gradient outlines color overlay patterns are generated for digital comparison; **E)** Scanned model casts are uploaded in IC measure software for odontometric triangle measurements.

Missing teeth
Fractured teeth
Mobile teeth
Condition of the periodontium
Maxillary and mandibular tori
Tongue and lip piercings and/or jewelry
Other unusual intraoral features or anomalies

vi. Impressions:

Maxillary and mandibular impressions should be taken. Both conventional and digital impression techniques utilized in clinical dentistry are acceptable. For conventional impressions, ADA-listed materials should be used following established dental impression techniques. Dental casts should be produced from impressions following established techniques.

For digital impressions ADA-listed optical scanner and laser scanner techniques are acceptable. The digital files from the scans can be used for digital analyses utilizing appropriate software techniques. Alternately, the digital files can be used following established techniques to produce physical dental casts

If removable prostheses are present, impressions should be made both with and without the prosthetic appliances in situ. The inter-occlusal relationship should be recorded using ADA-listed materials and techniques.

vii. Sample or test bites

Bite marksshould be recorded using ADA-listed materials such as modelling wax, Styrofoam sheets, bite registration wax and appropriate techniques in centric occlusion, edge-to-edge bite and in protrusive and lateral excursions of the jaws. These positions are again duplicated and one set of wax bite registrations can be used to set the study models on a dental articulator and the other set of wax bite registrations is used for comparison of the imprints with those of the bite marks. These items should be labeled, photographed, and retained.

viii. Dental casts:

If physical casts from either conventional or digital impressions are produced, master casts should be prepared by ADA-listed Type III dental stone prepared according to manufacturer's instructions should be used following established dental techniques. Additional casts can be poured from polyvinylsiloxane or polyether impressions or fabricated from digital files. Each subsequent model poured should be sequentially labeled to indicate the order of production.

If the original conventional impressions are taken using alginate or similar materials, duplicate casts can be produced from an impression of the master cast made using ADA-listed materials for duplication. Duplicate casts should be appropriately labeled and the master cast utilized to produce the duplicate should be noted andall tests and experiments should be performed using them.[13]

Bite mark evaluation:

Methods for analysis of bite marks can be broadly classified as Manual methods, Semi-automatic methods, and Automatic approaches[14]. Under Manual procedures, there are hand tracing, wax impression tracing, radiopaque wax impression tracing, and xerographic techniques,[15] which involve the generation of overlays or bite patterns using acetate sheets manually by experts in forensic dentistry. Semi-automatic methods deal with digital imaging analysis by scanning the study models. Images are processed by computer applications like Adobe Photoshop, which uses 2d polyline, magic wand, and painting tools[16]. Some of the software's used for bite mark analyses are IC MEASURE[17] for angular and linear measurements, DENTALPRINT[18], and BITEPRINT[19] software'sfor overlay generation and comparison. MESH COMPARISION and CLOUD COMPARISION[20] software are for 3- dimensional analysis. Image perception technology has emerged to bite mark analysis using different grey values in the picture to generate overlays. (Velden et al.2006). As there are certain limitations with the usage of software such as complexity in programming, computational errors, low accuracy, low efficiency still advanced methods are to be implemented.

Manual Methods: (Table: 1)

1) Hand tracing technique:

In this method, acetate sheets are placed on biting surfaces of upper and lower anterior teeth of study casts and depicting the overlays and compared. (Fig. 1C)[11]

2) Wax impression technique:

In this method, bite marks are recorded using modeling wax by pressing the model casts onto it, and impressions were traced on the acetate sheet (Fig. 1D&E)[11].

3) Radiographic wax impression technique:

In this method, silver amalgam powder is mixed with surgical spirit and added to tooth impressions in the modeling wax sheet. Then radiograph is taken on intraoral occlusal x-ray film it is processed. The bite marks will be depicted as white teeth edges on dark background. It was then traced on a transparent or acetate sheet.[11]

4) Xerography:

In this method, the maxillary and mandibular study casts were placed on a glass plate of a photocopy machine with incisal edges contacting the plate. This was copied on A4 paper, and then the acetate sheet is placed over it, and the outline of incisal edges are marked as overlays.[11]

Digital Methods: (Table: 1)

Software's and tools used in digital methods are:

1) 2D polyline:

In this method, study casts are scanned using a 2D scanner plate, placing the biting towards the plate, and an image is generated. Photoshop application is used. It depicts lines drawn from the tip of canines on either side and a perpendicular line passing between the incisal edges of central incisors. The angles between those lines are measured and recorded. The painting tool is also used for highlighting canine-canine width, tooth width, thickness in colors, and is measured and recorded for comparison[12].

2) IC Measure:

In this software odontometric triangle is used- lines are drawn from most convex areas of canines, and the midline between

central incisors and their internal angles, mesiodistal widths of all anterior teeth, intercanine distance were measured[13] (Fig. 2E).

3) Dental print:

This software firstly selects six upper and lower anterior teeth, and a contact plane was created from three highest points on 3D images of dental casts from which biting edges were obtained, which allows contact plane deep into the teeth, and then the comparison is done between overlays generated from 3D images of dental casts and bite mark impressions[14].

4) Image perception technology:

In this method photograph of the bite mark is opened in image perception software, and it adds color to different greyscale areas of the image and regions of similar grey values are selected, regions exhibiting pixel intensity are part of bite marks and remaining regions are excluded, result image shows a bite mark. The resolution is altered to be compatible with the original photograph, and opacity enhancements are done either increasing or decreasing to accommodate the suspect's overlays[21].

The evaluation classifies the matching of bite patterns as definite, probable, possible, weak and excluded, based on consideration of superimposition of overlay patterns of life-sized photographs (1:1) (Fig. 2 A, B, C&D), metric relations of mesiodistal widths, arch perimeters, rotation angles. Their difference between the model casts and wax bite impressions reveals the degree of matching leading to the conviction.

CONCLUSION

Human bite mark analysis occupied prominent status in forensic dentistry as it requires complicated process owing to distortion through skin elasticity, as the time elapsed between the production and the analysis, anatomical location of the injury, loss of data, contamination and subjective elements in fabrication and comparison are recurring problems for determining either manually or digitally, hence forensic odontologists should be aware of the best accurate and economical method applied in routine practice. When compared to manual methods, where they require qualified forensic odontologists to trace the overlays from study models, wax bites, occlusal radiographs, and cast scanned copies. Due to objective errors of humans, machines came to play a crucial role in overlay generation by using computational software, linear and angular measurements, and greyscale values of the image. Even then, limitations exist for digital or automated methods such as computational errors and complexity and less accuracy than required. Further research should be carried out to develop more accurate methods for bite mark analysis using newer methods such as Artificial intelligence, Neural architectures as digital methods are more accurate and less time-consuming even if larger sample sizes are to be analyzed.

Table 1: explains about advantages, disadvantages and limitations of both Manual and Digital methods

Methods	Materials and methods	Advantages	Disadvantages	Limitations
Manual methods a) Hand tracing	Study casts, acetate sheets	1) Economically feasible. 2) Less time consuming. 3) Does not require skills to manage electronic devices and software's.	Needs a high level of practical expertise, Objective errors	Manual records can't be maintained for longer durations and also can be easily manipulated.
b) Wax impression tracing	Modeling wax, acetate sheets		Change in Physical properties of wax by the time factor, Objective errors	
c) Radiographic wax impression tracing	Silver amalgam powder, surgical spirit, modeling wax, intraoral occlusal x-ray film, acetate sheets		Radiographic exposure, Objective errors	
d) Xerography	Study casts, glass plate, photocopy machine, acetate sheet		Objective errors	
Digital methods a) 2d polyline	Linear measurements	1) Digital methods are easy to perform. 2) Time factor – larger sample sizes can be analyzed in shorter period of time.	1) Digital methods require software skills, which most of the dentists are not acquainted with. 2) These methods require a computer and 3d scanning machines, which are expensive.	Limitations for software analysing methods are computational errors and complexity, decreased accuracy, and efficiency.
b) IC measure	Angular measurements			
c) Dental print	Overlay generation			
d) Mesh\cloud comparison	3d comparison			
e) Image perception technology	Greyscale values of the image			

REFERENCES

1. A. Bewick, Greener EP. Awareness of forensic odontology among dental practitioners in Chennai: A knowledge, attitude, practice study. 2011. p. 63–6.

2. Stuart R. Batten, Niel R. Champness, Xiao-Ming Chen, Javier Garcia-Martinez, Susumu Kitagawa, Lars Ohrstrom, Michael O'Keeffe, Myunghyum Paik Shu JR. Ref_2.PDF. Vol. 85, Pure Appl. Chem. 2013. p. 1715–24.

3. shafer, hine L, Conclusiones TVII, Contemporáneo PDEUSO, Evaluaci T V, Ai F, Jakubiec JA, et al. shafers textbook of oral pathology. elsevier. 2012. 1689–1699 p.

4. Saks MJ, Albright T, Bohan TL, Bierer BE, Bowers CM, Bush MA, et al. Forensic bitemark identification: weak foundations, exaggerated claims. J Law Biosci. 2016;3:538–75.

5. Tai MW, Chong ZF, Asif MK, Rahmat RA, Nambiar P. A comparative study between xerographic, computer-assisted overlay generation and animated-superimposition methods in bite mark analyses. Leg Med. 2016;22:42–8.

6. Tanha khan, M. K. Sunil, Garima yeluri, Shilpi Srivastava, Megha Srivastava, Aimanmehfooz. Bite Marks: The Odontologic Metaphor For Finger Prints. TMU J Dent Vol 7; Issue 1. Jan-March 2020.

7. Rao DS, Ali IM, Annigeri RG. Bitemarks-A review. Journal of Dental Research and Review. 2016 Jan 1;3(1):31.

8. Pretty IA, Sweet D. A paradigm shift in the analysis of bitemarks. Forensic Sci Int. 2010;201:38–44.

9. Forrest A, Soon A. Bite marks. Forensic Odontology: Principles and Practice. 2016 Jan 26:228-85.

10. Souviron R, Haller L. Bite mark evidence: Bite mark analysis is not the same as bite mark comparison or matching or identification. J Law Biosci. 2017;4:617–22.

11. ABFO. American Board of Forensic Odontology standards and guidelines for evaluating bitemarks. 2018 30/07/2019].

12. Bite mark analysis in forensic odontology, kaur sandeep - 2021 Oct 4.

13. American Board of Forensic Odontology. Standards and Guidelines for Evaluating Bitemarks. Am Board Forensic Odontology. 2018;1–28.

14. Mahasantipiya PM, Yeesarapat U, Suriyadet T, Sricharoen J, Dumrongwanich A, Thaiupathump T. Bite mark identification using neural networks: A preliminary study. IMECS 2011 - Int MultiConference Eng Comput Sci 2011. 2011;1:65–8.

15. Maloth S, Ganapathy KS. Comparison between five commonly used two-dimensional methods of human bite mark overlay production from the dental study casts. 2011;22:499–505.

16. Lorkiewicz-muszynska D. The Effectiveness of 2D and 3D Methods in the Analysis of Experimental Bite Marks. 2015;

17. Raina P, Kulkarni N, Shah R. A comparative study of sagittal dental relationship using digital method of bite mark evaluation. J Forensic Dent Sci. 2019;11:125.

18. Torres JC, Phys D, Ph D, Luna-del-castillo JD, Ph D, Ã MA. Effectiveness of Comparison Overlays Generated with DentalPrint r Software in Bite. 2007;52:5–10.

19. Ramos B, Torres JC, Molina A, Martin-de-las-Heras S. A new method to geometrically represent bite marks in human skin for comparison with the suspected dentition. Aust J Forensic Sci. 2019;51:220–30.

20. Karim N, Norbert T, Delphine M, Universitaire CH. Version of Record.

21. Velden A Van Der, Spiessens M, Willems G. Bite Mark Analysis And Comparison Using Image Perception Technology. 2006;24:14–7.