International Journal of Community Medicine and Public Health
Zahrani AA. Int J Community Med Public Health. 2024 Jun;11(6):2468-2475
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20241514

Review Article

Current trends in the methods of identification in forensic dentistry: a review of literature

Ahmed A. Zahrani*

Department of Oral and Maxillofacial Surgery, College of Dentistry, King Saud University, Riyadh, Saudi Arabia

Received: 28 April 2024
Accepted: 18 May 2024

***Correspondence:**
Dr. Ahmed A. Zahrani,
E-mail: azahran@ksu.edu.sa

ABSTRACT

Dental evidence in forensic investigation has been in practice for many years. Forensic dentistry or forensic odontology predominantly involves the identification of human remains, by comparing the dental evidence of deceased persons recovered from the scene of an accident or a crime (post-mortem dental data) with the ante-mortem dental records. The use of dental identification lies in the fact that no two oral cavities are alike, and the teeth are unique for everyone. In addition, dental structures are not only the hardest and most protected structures in the body, but are also the most resistant to degradation due to environmental impact. Identification of a deceased individual using forensic odontology is possible with a higher degree certainty, as it is possible to apply multiple tools such as dental imaging, tongue print, lip print, rugoscopy, tooth signature, ameloglyphics, deoxyribonucleic acid (DNA) analysis, bite-marks, dentures and prosthesis, facial reconstruction, virtopsy and software applications. Since the role of a forensic dentist extends even beyond identification, especially in the absence of ante-mortem dental records for comparison, teeth become a determinant factor in identification, and determination of age, gender and ethnicity. Although several methods and techniques of identification have been described in forensic dentistry, there is no comprehensive resource that describes them all in detail. Therefore, this review paper aims to analyze and discuss the available methods of identification in forensic dentistry, their merits and limitations, and how they might be of help to the forensic dentists and pathologists.

Keywords: Forensic dentistry, Forensic odontology, Deceased identification, Criminal dental records, Medicolegal data

INTRODUCTION

The specialty of forensic dentistry was first introduced by Oscar Amoedo, an artist from Paris, France, in the late 1890s, and for the first time it became an instructional program in the United States dental school curriculum, in the 1960s.[1,2] Since then forensic dentistry has been recognized as an integral part of the medicolegal system, offering valuable help in the detection and resolution of criminal cases.[3,4] Identification of unknown dead bodies, human remains and the analysis of bite marks utilizing teeth and dental features form the mainstay of forensic dentistry, which is also termed as forensic odontology.[3,5] However, in the last few decades, the scope of forensic dentistry has extended beyond identification, and has been employed for age estimation, determination of gender and ethnicity of an individual.[6] It is acknowledged that identification of unknown human bodies is of paramount importance for legal and humanitarian reasons including issuing certificates of death and settlement, disbursement of insurance policies and pension proceeds, and abstraction of grief for involved families.[7]

Establishing the identity of unknown deceased persons is traditionally carried out by the relatives or next of kin.[8] This is usually done by visual examination of body features and by identification of surgical scars, tattoos, moles, birth marks or the presence certain skin diseases or features.[9] In addition, the recognition of a deceased person's bodily possessions such as jewellery and articles of clothing are contributory indicators in the process of identification.[10] Other potential evidence, which could help in forensic

identification and requires the pathologists or forensic dentists, is the presence distinctive medical conditions such as bone deformities and skin tumors, and implanted medical devices with unique serial numbers, like pacemakers, joint prosthesis and implants.[11]

One significant aspect of the field of forensic dentistry is its ability to help identify mortal remains based on dental tissues, which are capable of remaining intact for millennia by virtue of their resistance to the natural processes of decomposition and biodegradation.[11] Furthermore, in natural mass disasters like earthquakes, tsunamis, landslides, floods and in man-made disasters such as terrorist attacks, bomb blasts and mass murders, the involved bodies are likely charred, mutilated, decomposed or dismembered, thereby rendering the dead bodies unidentifiable, except through dental tissues.[6] Therefore the aim of the present review is to shed light on the various biological and physical methods of identification reported in forensic dentistry, for the purpose of identifying deceased individuals.

DENTAL IMAGING

Since its introduction, dental imaging has played an important role in the forensic identification of unknown dead bodies through examination of unique dental structures and bony anatomical landmarks. Standard dental films are the choice tools for evaluation of detailed dental features, diseases and deformities of the jaw bone and teeth based restorations.[12] On the other hand, panoramic radiographs help in the evaluation of the entire oral and maxillofacial region for diseases and anomalies.[13] Newer imaging modalities like cone beam computed tomography (CBCT), regardless of their technical limitations, provide in-depth information about finer anatomical details such as bone density and pathologies not detectable by conventional radiography.[14] According to Hassanaly et al, use of CBCT proved to be an accurate tool for age estimation based on the technique of studying pulp narrowing, in addition to sex estimation, and identification of individuals using bite-marks analysis, and facial reconstruction.[14] In forensic identification using dental imaging, the process of matching and exclusion is a deliberate process in which comparison is established between the most reliable data recorded from the victim, when alive (ante-mortem data), and those of a dental record, after death (post-mortem data). Therefore, the availability of previous dental radiographic images and recordings are crucial. In this context, routine dental radiographic records retained by dentists are relatively inadequate. It is therefore imperative to standardize international recommendations regarding maintenance of dental records, including radiographs.[15]

Based on a study conducted at King Saud University, College of Dentistry, when old and new dental records and radiographs of randomly selected dental patients, were compared as ante-mortem and post-mortem data, respectively, there was approximately 80% positive identification.[16] Although the study reported greater accuracy for identification using dental imaging and clinical data, there was apparent mismatch and discrepancy attributed to either changes in the patients' dentition over time or due to human error during examination and recording of data.[16] Forensic identification using dental imaging is made by point-to-point comparison of a set of radiographs. All points of comparison must match their counterparts in the exact way and the difference must be justified for further explanation.[15] While the role of radiography in identification is reliable and has been used over several years, in the last decade, digital radiography has become the choice of imaging for forensic identification of deceased persons.[14] When this is combined with computer-based dental chart matching software, fast and reliable identification could be expedited using efficient and accurate methods.

TONGUE PRINT

The use of tongue print is a relatively new concept in forensic dentistry. The arrangement of papillae and ridges make the tongue a unique tool for identification. Tongue print has a similar presentation to that observed in finger, palm and footprints. Being a unique organ, tongue print can be a reliable biometric authentication tool comparable to other biometric tools.[17] As a method of identification, tongue print has been proven to be a useful tool in forensic dentistry, particularly when used in conjunction with cheiloscopy and rugoscopy.[18] Several techniques have been introduced and reported for capturing the unique features of the tongue surface. An impression of the tongue including the dorsal surface and lateral borders reveals the surface characteristics fully and can serve as a permanent record.[19] Although the conventional methodology for recording tongue prints involved the use of glass plates, a more sophisticated method using special film has been used lately and the technique is reportedly improved by contrast medium and utilization of infrared photography.[20] Furthermore, the use of video capturing and digital software technology offers a new dimension in the images analysis of tongue prints, wherein color and hue adjustment could enable database matching for possible positive identification.[21] The use of tongue print is a potential biometric tool and with ongoing research and validation, the technique's reliability appears to be promising.

CHEILOSCOPY AND LIP PRINT

Criminals often hide their identity by wearing gloves, making their identification impossible due to the lack of sufficient evidence. In such circumstances, a different method of identification becomes imperatively needed. The technique of cheiloscopy and lip print is known as lip biometrics. It basically relies on the uniqueness of lip features such as pattern, shape, size, lines, grooves, furrows and wrinkles.[22] These features were first noted and reported by the anthropologist Fischer in 1902, and their practical use was recognized by scientists several year

later.[23] Based on a technique developed by Suzuki and Tsuchihashi, scientists have categorized the lines of the lip and described their patterns into either vertical, branched, reticular, intersected or undetermined patterns.[24,25] The technique of cheiloscopy which is used as an alternative for lip print, implies the analysis of the external surface of the lip (red zone).[26] From a forensic perspective, lip prints are most often seen on glassware, cutlery, cigarette butts and may also be found on surfaces of other articles in a crime scene and could possibly link a suspect to the crime. In addition, lip prints could potentially play a role in sex determination thereby making it easy to shorten the array of suspects with motive behind the crime.[24,27] Although cheiloscopy and lip print are considered as additional evidence, their use along with supplementary methods such as bite mark and DNA profiling expands the possibilities of identifying a deceased individual.[28] Overall, the technique of lip print requires a standard and uniform procedure that must be adopted while collection and recording in order to ensure accurate comparison.

PALATAL RUGOSCOPY

Rugae is a projected anatomical structure found on the anterior part of the palate. These structures vary in appearance and appear as irregular, asymmetric, and curved ridges. They have unique arrangements with individual variations in each person. Rugae are present for life, starting at the third month of intrauterine life and are preserved by oral and para-oral structures over a lifetime, thereby making them less affected by environmental transformation.[29] Studies have shown that the palatal rugae are unique for every individual, and similar to fingerprints, they are stable and can be used a reliable reference for human identification.[30-34] The study about the patterns of the hard palate rugae is commonly referred to as palatal rugoscopy. This technique analyses the size, shape, direction, and arrangement of rugae for identification purposes. Several classifications of palatal rugae have been described in the literature, based on shape, length, numbers, and orientation. Likewise, various methods on how to use them for identification have also been described. The application of computer-based analysis of the palatal rugoscopy images has ultimately enhanced the reliability and accuracy of the technique. Although palatal rugae are highly individualistic, the reliability of rugoscopy is undermined by aging, trauma, orthodontic treatment, and by certain medical and pathological conditions.[34] Nevertheless, this technique is useful as a complementary method and in conjunction with other methods of identification.[30,35]

TOOTH PRINT (THE TOOTH SIGNATURE)

Biometric based identification and verification such as fingerprint, iris scanning, and facial recognition have been used successfully and these techniques have improved further with automated systems and software.[36] These identification methods may not be completely reliable for identification, as they become unreproducible when bodies are decomposed, burned, or only small fragments of calcified tissues are available at the crime scene. Instead, the tooth prints, known as tooth signature, has been suggested as a reliable tool for individual identification. This is because for each individual, the set of teeth and their microstructure are unique and it also differs between males and females.[37] In forensic dentistry, tooth print is a term used to describe the pattern of enamel rods, which are highly calcified and distinctive structures within the enamel of a tooth and are resistant to decomposition and damage by fire or unfavorable environmental conditions.[37] The enamel rods are laid down by the ameloblasts, the enamel forming cells, during tooth development, leaving behind a prism morphology and never undergo remodeling.[38] The specific study of enamel rod patterns is also termed as ameloglyphics, which could be employed as a reliable biometric tool for human identification.[39] This potential technique is promising and can be used as an adjunct tool with other conventional biometrics for better identification of deceased individuals.

DENTURE AND PROSTHETIC IDENTIFICATION

Denture and prosthetic identification are valuable tools in forensic dentistry when used in conjunction with other methods of identification. Denture design details, photographs and information about the materials used in denture fabrication provide adequate enough information for identification of an individual.[40,41] Denture labelling is a method by which unique user details are engraved on the denture surface, either manually or by computer printed micro labelling system and barcoding. The practice of engraving fixed restorations and dentures is highly acknowledged and recommended for each dental patient.[42] In order to enable post-mortem identification, such methods of micro labelling must be efficient, easily identifiable, durable and resist damage by fire or extreme environmental conditions. At the same time, these micro labels should be biologically inert and not affect the esthetics.[43]

DNA ANALYSIS

DNA analysis in forensic dentistry focuses on analysis of biological substances found in or associated with the incident site. These substances include, but are not limited to, saliva, hair bulbs and tissue samples retrieved from objects and articles recovered from the crime scene. The DNA profile is investigated in specialized forensic laboratories using polymerase chain reaction (PCR) of short tandem repeat (STR) sequences, mitochondrial DNA and single nucleotide polymorphisms (SNP).[44] The role of DNA in identification of human remains is endorsed successfully in cases of mass disaster, fire and homicide, especially when the dead bodies are severely changed or decomposed.[45] The structure of DNA allows characterization of every individual based on the nucleotide sequence, which is referred to as DNA fingerprint. In addition to their role in identification of unknown persons, DNA analysis plays an important role

in the identification of bite marks left on victims or perpetrators and it may link evidence to a potential suspect.[46] It is also widely accepted that DNA analysis plays a role in parentage testing and identification of ancestry.[47,48] Despite all environmental influences, the recovery of DNA from human remains is not affected by temperature, humidity and pH media, and this is further enhanced in dental tissues, which are most resistant to hazardous circumstances. Therefore, in the case of severely decomposed bodies, extraction of DNA is feasible from dental pulp tissues, wherein a substantial amount may be collected without difficulty.[45,49] Establishing positive identification using DNA analysis is frequently complemented by other tools such as X-ray, dental charts and photographs, which ultimately reinforce and expand the logical basis for identification.

ANALYSIS OF BITE MARKS

Marks left behind by teeth and dental tissues, on human skin and soft tissues, in various criminal and assault cases are referred to as bite marks. These are most often related to sexual offenses, interpersonal altercations and/or homicides. Human bite marks can be found on any part of the body, but are seen more often on the victim's breasts and legs secondary to sexual assault, and also on the arms and shoulders of the aggressor.[4] Analyzing the pattern of the bite marks allows the identification of a suspect or link a suspect to the crime scene. The diameter of the human bite varies in size, which usually is presents with a central contusion zone and extravascular bleeding, caused by teeth pressure. The severity of injury would explain the force, impact, angle and dynamics of an altercation. Since the bite mark is liable to alteration due to bleeding, edema and time lapse, it is so important to preserve the bite marks by taking immediate photographs marked with scale ruler or by obtaining an impression of the bite surface.[50] Using fine impression materials such as vinyl polysiloxane or polyether offers a defined registration of dental features, which contribute to effective matching and exclusion procedures. The recent use of computer aided software and digital imaging techniques has many advantages that has enhanced the bite measurement and analysis, and has expanded the bite marks database. Despite all these efforts, bite marks analysis is still bounded by certain limitations, which make its use liable to potential error in identification, even with the use of a bite mark database.[50,51] Thus, employment of another method becomes inevitable for easy identification. The collection of aggressor saliva deposited in the skin of a victim at the time of biting or even observed on certain articles like chewing gum or cigarette butts is valuable for further investigations such as amylase detection. The collection of saliva is preferably done using double swab under strict policy and standard protocol to eliminate the risk of contamination. Determination of the ABO blood groups, and isolation of bacteria and other microorganisms found in the bite mark, which may mimic the oral milieu of the perpetrator, and DNA analysis would provide more objective and reliable methods for identification.[50,52]

FACIAL RECONSTRUCTION

Making a model of an individual's face out of skeletal remains is a useful means of forensic identification and investigation. The process of facial reconstruction involves a thorough analysis of skeletal remains to determine their anatomic structure and the unique bony features. Several technical approaches have been used for forensic facial reconstruction, which include plastic sculpturing and computer-based methods. For both the methods, prediction of facial features is based on the average facial proportions of the individual, wherein the technique is further optimized by considering unique variations such as age, sex and anthropological characteristics. The plastic sculpturing method, although still in practice, is considered a legacy technique, and is being seldom used ever since the advent of computer-based methodologies.[53] Computer assisted facial reconstruction has emerged as a revolutionary new technology, and is capable of creating multiple reproducible 3D representations. Based on skeletal data acquisition using digital radiographs and computed tomography (CT), this technique is fast, precise and increases the probability of identifying a missing or deceased individual.[54] Whether the reconstruction is attempted virtually or in reality, the facial surface is projected by either reconstruction of the craniofacial anatomy or by mathematical extrapolation of the skeletal surface of the skull or through a combination of both techniques.[55] Although the technique of digital superimposition of post-mortem skull photographs over ante-mortem facial photographs has been tried, this technique is liable for uncertainty and is therefore best used in conjunction with other methods of identification.[56] Due to the similar facial features possessed by several individuals, facial reconstruction cannot be regarded as the only method of positive identification, and it would at best be used for exclusion rather than identification.

VIRTOPSY

Recent technological advances have led to the development of a new dimension in examination of dead bodies. The virtual autopsy or scalpel free technique is a bloodless autopsy procedure, introduced for the first time in 2002, at the University of Bern in Switzerland, by Dr. Richard Dimhofer.[57] It uses three-dimensional imaging technology for obtaining images of the inner and outer aspects of the body using a combination of medical-grade CT and magnetic resonance imaging (MRI). The data obtained is stored in the form of multi-slice digital CT/MRI images, thereby giving an advantage of interlinking different branches of forensic sciences together. This technique has been improved lately by the use of robots for quick and accurate standardized examination. Virtual autopsy or virtopsy, as it is shortly called, appears to be a helpful and complementary tool for dental and medical cadaveric examination.[58] However, the interpretation of evidence from this technique may appear to be subjective and could be considered with caution in the courts of law and could be subjected to further liability and

interpretation.[59] Despite its limitations, the technique is still beneficial particularly with decomposed or contaminated dead bodies, and its overall advantages outweigh its shortcomings. Moreover, in cultures where conventional autopsy is not acceptable, Virtopsy alleviates immense psychological distress and sociodemographic opposition.[60] Lastly, it also has the unique advantage of archiving post-mortem data, which could be easily retrieved for medicolegal examination from any location.

VIRTUAL COMPARISON MICROSCOPY

Virtual comparison microscopy (VCM) is a digital imaging system used for simultaneous comparison and analysis of two dental sources of evidence, utilizing two high-resolution optical cameras. In comparison to conventional microscopy, the main advantage of this method is that the examiner does not need to rely on his or her memory when comparing images.[56]

The captured images are displayed on a computer screen and can be manipulated, enhanced and stored electronically. This digital technique offers easier examination and enhances the accuracy and efficiency of identification. It provides simultaneous viewing and measurement of the similarities and differences. Based on a comparative study to analyze bite-marks, this technique was shown to provide better characterization of the patterns and alignment of a suspect's bite-mark and the dental features confined within.[61] Despite the advantages of this technique, its accuracy might be affected due to distorted resolution and inadequate lightening during image capturing, and therefore, requires a highly trained and experienced examiner at all times.[62]

SOFTWARE IN FORENSIC DENTISTRY

The identification of the deceased is usually carried out visually by the next of kin. However, this method is neither reliable, nor desirable when the scenario involves multiple fatalities, decomposed or mutilates bodies, and in cases of violent deaths, accidents or brutal murders.[63]

Under such circumstances, digital forensic science plays an important role in the identification process and comparison analysis. In recent times, computer-based digital technology has grown vastly to become an integral part of our daily lives, and the field of forensic science and forensic dentistry are no exception to that. This has led to the development of the specialty called, "computer forensics".[63]

Numerous sophisticated software has been designed over the past few years to improve examiner efficiency, interpretation, presentation, recording, and comparison of ante-mortem and post-mortem evidences.[64] These tools not only facilitate and enhance forensic practice, but also revolutionize the way in which a forensic odontologist deals with criminal cases. Although the inherent efficiency of computer assisted software makes them extremely beneficial in legal proceedings, practitioners need to possess a basic knowledge of computer technology for proper utilization. Moreover, the optimum use of this technology requires appropriate computer equipment and software, combined with strong national and international database of forensic dental records.[65]

Table 1 lists some of the available software applications and their potential scope for use in forensic odontology.

Table 1: Software application in forensic dentistry.

Software type	Application in forensic dentistry
Dental image management software	Analysis of images and photographs
Dental comparison software	Comparison of dental features and morphology, restorations and dental anomalies
Bite mark analysis software	Analysis of bite mark
Database management software	Storage and retrieval of data
3D dental modeling software	Creation of 3D virtual models for teeth and jaws
Forensic odontology case management software	Management of forensic case work
Forensic odontology data analysis software	Analysis of large data
Forensic imaging software	Examination, analysis and presentation of digital evidence
Optical character recognition (OCR)	Conversion of typed and handwriting or printed text into images machine-coded text
Skeletal analysis software	Age estimation and skeletal based identification and bone analysis
Facial reconstruction software	Creation of 3D virtual face
Firearms identification software	Capture and compare and digitally store images of bullets and cartridge casings
Data analysis and visualization software	Data and images recording and interpretation
Palatal rugae comparison software	Matching the clinical photographs of palatal rugae

AGE ESTIMATION AND GENDER DETERMINATION

Estimating the age of a deceased person using their teeth was reported for the first time by Gustafson (1950), and this was based on the stage of tooth eruption, root formation and tooth mineralization.[66] As a person ages, the degree of dental wear and attrition proves to be adequate enough to provide further insights into the age prediction. Likewise, estimating the chronological age of a tooth by studying the deposition of hydroxyapatite layers within the dentinal tubules (secondary and tertiary dentin layers) and by enumerating the number of deposited cementum layers (cementum annulation and cementum incremental lines) were considered as reliable parameters for age determination.[67] One more method reportedly used for age estimation in forensic dentistry was based on histological evaluation of cranio-caudal osteoblastic activity. This was devised by way of observing the intraosseous Haversian canal systems, its expansion combined with reduction in osteoblast number, and changes to the cortical bone porosity. Besides age estimation, identifying gender through forensic dentistry is an additional tool in the process of identification. The sexual dimorphism between males and females is discriminated by evaluation of the palatal rugae, size and shape of the teeth, particularly the canine teeth, molars and Carabelli's tubercle. Although many studies have attempted to link analysis of lip print to gender determination, the low level of certainty of the evidence has led to the belief that lip print (cheiloscopy) would not be a reliable tool to evaluate sexual dimorphism.[24] Studying the anatomical differences between males and females, at the level of the skull base, can also be of help. In this context, the cranium of a male individual is significantly larger, thicker, heavier, and of greater volume. On the contrary, the female cranium is thinner, smaller and has softer contours with bone crests and protuberances that are not prominent.[68] Chromosomal analysis of the dental pulp tissue to identify the presence of chromosome "X", is yet another alternative method for the determination of gender in forensic dentistry. Interestingly, dental pulp tissue appears to be the only viable source for genetic material in cases involving incineration, immersion, trauma or decomposition, as the teeth are among the most resistant hard tissues to unfavorable environmental impact.[69]

CONCLUSION

The role of a forensic dentist or pathologist extends beyond identification into the realms of medicolegal consulting for resolution of criminal cases. The significance of their roles is emphasized by their ability to contribute to cases where other forensic records are unavailable. In the absence of ante-mortem records, teeth become a determinant factor not only for identification, but also for determination of age, gender and ethnicity. It is imperative that all dentists learn and understand about the different methods and techniques of identification described in forensic dentistry. Lastly, forensic dentists and pathologists need to possess comprehensive knowledge about these methods, their individual merits and limitations, and how they might be of help in solving criminal cases.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Amoedo O. The Role of the Dentists in the Identification of the Victims of the Catastrophe of the "Bazar de la Charite," Paris. The Dental Cosmos. 1897;39(11):905-12.
2. Silver WE, Souviron RR, editors. Dental Autopsy. 1st Edition ed. Boca Raton: CRC Press. 2009.
3. Avon SL. Forensic odontology: the roles and responsibilities of the dentist. J Canad Dent Assoc. 2004;70(7):453-8.
4. Sweet D, Pretty IA. A look at forensic dentistry – Part 2: Teeth as weapons of violence – identification of bitemark perpetrators. Br Dent J. 2001;190(8):415-8.
5. Al-Eid RA, Ramalingam S, Sundar C, Aldawsari M, Nooh N. Detection of Visually Imperceptible Blood Contamination in the Oral Surgical Clinic using Forensic Luminol Blood Detection Agent. J Int Soc Prev Comm Dentistry. 2018;8(4):327-32.
6. Krishan K, Kanchan T, Garg AK. Dental Evidence in Forensic Identification - An Overview, Methodology and Present Status. Open Dentistry J. 2015;9:250-6.
7. Cattaneo C, De Angelis D, Mazzarelli D, et al. The rights of migrants to the identification of their dead: an attempt at an identification strategy from Italy. Int J Legal Med. 2023;137(1):145-56.
8. Lucassen AM, Parker M, Wheeler R. Role of next of kin in accessing health records of deceased relatives. BMJ. 2004;328(7445):952-3.
9. Kulshreshtha M, Mondal PR. Acquired body marks: A mode of identification in Forensics. J Forensic Legal Med. 2017;52:98-109.
10. Caplova Z, Obertova Z, Gibelli DM. Personal Identification of Deceased Persons: An Overview of the Current Methods Based on Physical Appearance. J Forensic Sci. 2018;63(3):662-71.
11. Kumar A, Harish D, Singh A, Kulbhushan, Kumar GA. Unknown dead bodies: Problems and solutions. J Indian Acad Forensic Med. 2014;36:76-80.
12. Manigandan T, Sumathy C, Elumalai M, Sathasivasubramanian S, Kannan A. Forensic radiology in dentistry. J Pharm Bioallied Sci. 2015;7(1):S260-4.
13. Lundberg E, Mihajlovic NS, Sjöström M, Ahlqvist J. The use of panoramic images for identification of edentulous persons. J Forensic Odonto-stomatol. 2019;37(2):18-24.
14. Hassanaly M, Caldas I, Teixeira A, Pérez-Mongiovi D. Application of CBCT Technology in Forensic Odontology: A Narrative Review. Curr Forensic Sci. 2023;1.

15. Reddy BNK, Swetha P, Manyam R, Supriya AN. Importance of dental radiography in forensic odontology: A Review. Oral Maxillofac Pathol J. 2022;13(2):124-7.
16. Zahrani AA. Identification of unidentified human remains - validity of dental records. Pak Oral Dent J. 2005;25(1):3-6.
17. Zhang D. Biometric Solutions: For Authentication in an E-World. 2002.
18. Khan T, Manna A, Saaduddin A, Bashir T, Ahmad N. Tongue prints- Unique as well as potential forensic tool for biometric authentication. Archive Dent Res. 2023;13:10-4.
19. Radhika T, Jeddy N, Nithya S. Tongue prints: A novel biometric and potential forensic tool. J Forensic Dent Sci. 2016;8(3):117-9.
20. Jeddy N, Radhika T, Nithya S. Tongue prints in biometric authentication: A pilot study. J Oral Maxillofac Pathol. 2017;21(1):176-9.
21. Javed AR, Jalil Z, Zehra W, Gadekallu T, Suh D, Jalil Piran M. A comprehensive survey on digital video forensics: Taxonomy, challenges, and future directions. Engineer Applic Artificial Intelligence. 2021;106:104456.
22. Prabhu RV, Dinkar AD, Prabhu VD. Collection of Lip prints as forensic evidence at the crime scene – An insight. J Oral Health Res. 2010;1:129-35.
23. Kasprzak J. Possibilities of cheiloscopy. Forensic Sci Int. 1990;46(1):145-51.
24. Franco A, Lima LKG, de Oliveira MN. The weak evidence of lip print analysis for sexual dimorphism in forensic dentistry: a systematic literature review and meta-analysis. Scientific Rep. 2021;11(1):24192.
25. Utsuno H, Kanoh T, Tadokoro O, Inoue K. Preliminary study of post mortem identification using lip prints. Forensic Sci Int. 2005;149:129-32.
26. Jaishankar S, Jaishankar N, Shanmugam S. Lip prints in personal identification. J Indian Acad Dent Specialists. 2010;1:23-6.
27. Sharma P, Saxena S, Rathod V. Cheiloscopy: The study of lip Prints in sex identification. J Forensic Dent Sci. 2009;1.
28. Dineshshankar J, Ganapathi N, Yoithapprabhunath TR, Maheswaran T, Kumar MS, Aravindhan R. Lip prints: Role in forensic odontology. J Pharm Bioallied Sci. 2013;5(1):S95-7.
29. R K, Gupta N, Bansal A, Vjim M. Palatal Rugae Pattern as an Aid for Personal Identification: A Forensic Study. J Indian Acad Oral Med Radiol. 2011;23:173-8.
30. Alshammari A, Farook FF, Alyahya L. A Morphometric Analysis of Palatal Rugae Patterns in a Saudi Arabian Population. Cureus. 2022;14(12):e33058.
31. Fahmi FM, Al-Shamrani SM, Talic YF. Rugae pattern in a Saudi population sample of males and females. Saudi Dent J. 2001;13(2):92-5.
32. Jacob RF, Shalla CL. Postmortem identification of the edentulous deceased: denture tissue surface anatomy. J Forensic Sci. 1987;32(3):698-702.
33. Mahajan R, Dar MA, Risam SS. Palatoscopy/rugoscopy: a potential tool in human identification. J Evol Med Dent Sci. 2014;3(40):10076-89.
34. Shamim T. The reliability of palatal rugoscopy in forensic identification. Ann Saudi Med. 2013;33(5):513-4.
35. Sanjaya PR, Gokul S, Prithviraj KJ, Rajendra S. Significance of Palatal Rugae: A Review. Int J Dent Update. 2012;2(2):74-82.
36. Bhattacharyya D, Ranjan R, Alisherov F, Minkyu C. Biometric Authentication: A Review. Int J U- E- Serv Sci Technol. 2009;2(3):13-27.
37. Juneja M, Juneja S, Rakesh N, Bhoomareddy Kantharaj YD. Ameloglyphics: A possible forensic tool for person identification following high temperature and acid exposure. J Forensic Dent Sci. 2016;8(1):28-31.
38. Christabel SL, Samuel M, Mohana Murali S, Haroon ALM, Devi M. Ameloglyphics - an updated review. Global J Res Analysis. 2021;44-6.
39. Beena VT, Mohammed R, Paul S, Stephen MM, Nair C, Mohan AP. Ameloglyphics: The Tooth Signature. Oral Maxillofac Pathol J. 2018;9(2):70-5.
40. Thomas J, Muruppel AM, Dinesh N, Gladstone S, Manjuran NG. Dentures in Forensic Identification - A Review of Methods & Benefits. J Adv Med Dent Sci. 2014;2(1):85-94.
41. Ramalingam S, Al-Hindi M, Al-Eid RA, Nooh N. Clinical evaluation of implant survival based on size and site of placement: A retrospective study of immediate implants at single rooted teeth sites. Saudi Dent J. 2015;27(2):105-11.
42. Kamath PG, Kamath VG. Engraved fixed restorations and denture micro-labelling to facilitate identification through forensic dentistry. J Indian Prosthodont Soc. 2005;5(2):79-81.
43. Venkat Nag PR, Shenoy KK. Dentures in forensic identification: A simple and innovative technique. J Indian Prosthodont Soc. 2006;6(2):75-7.
44. da Silva RH, Sales-Peres A, de Oliveira RN, de Oliveira FT, Sales-Peres SH. Use of DNA technology in forensic dentistry. J Appl Oral Sci. 2007;15(3):156-61.
45. Sweet DJ, Sweet CH. DNA analysis of dental pulp to link incinerated remains of homicide victim to crime scene. J Forensic Sci. 1995;40(2):310-4.
46. Ishikawa N, Nakamura Y, Naitou T, Miura Y, Kuroda H, Hashimoto M. Evaluating the reliability of DNA profiling of bite mark samples from living participants. J Forensic Res Crime Stud. 2021;6(1):1-9.
47. Essam K, Mona H, Diab A. Role of DNA in Paternity Testing. J Forensic Sci Criminal Inves. 2014;14(2):555882.
48. Rubanovich CK, Taitingfong R, Triplett C. Impacts of personal DNA ancestry testing. J Comm Genet. 2021;12(1):37-52.
49. Schwartz TR, Schwartz EA, Mieszerski L, McNally L, Kobilinsky L. Characterization of

deoxyribonucleic acid (DNA) obtained from teeth subjected to various environmental conditions. J Forensic Sci. 1991;36(4):979-90.
50. Sehrawat A. Controversies and Challenges in Bite Mark Analysis: A Comprehensive Review. Acta Scientific Dent Sci. 2023;7(10):64-70.
51. Ata-Ali J, Ata-Ali F. Forensic dentistry in human identification: A review of the literature. J Clin Exp Dentistry. 2014;6(2):e162-7.
52. Kavitha B, Einstein A, Sundharam S, Saraswathi TR. Limitations in forensic Odontology. J Forensic Dent Sci. 2009;1(1):8-10.
53. Stavrianos C, Stavrianou I, Zouloumis L, Mastagas D. An introduction to facial reconstruction. Balkan J Stomatol. 2007;11(2):76-83.
54. Khatri M, Misra D, Rai S, Misra A. Unfolding the mysterious path of forensic facial reconstruction: Review of different imaging modalities. MAMC J Med Sci. 2017;3(3):120-7.
55. Evison MP, Iwamura ESM, Guimarães MA, Schofield D. Forensic facial reconstruction and its contribution to identification in missing person cases. Handbook of Missing Persons. 2016;427-41.
56. Nagi R, Aravinda K, Rakesh N, Jain S, Kaur N, Mann AK. Digitization in forensic odontology: A paradigm shift in forensic investigations. J Forensic Dent Sci. 2019;11(1):5-10.
57. Badam RK, Sownetha T, Babu DBG. Virtopsy: Touch-free autopsy. J Forensic Dent Sci. 2017;9(1): 42.
58. Rosário Junior AFd, Souza PHC, Coudyzer W, Thevissen P, Willems G, Jacobs R. Virtual autopsy in forensic sciences and its applications in the forensic odontology. Revista Odonto Ciência. 2012;27:5-9.
59. Tejaswi KB, Hari Periya EA. Virtopsy (virtual autopsy): A new phase in forensic investigation. J Forensic Dent Sci. 2013;5(2):146-8.
60. Al Mulhim NK, Almulhim NF, Alabssi HA. The new era of forensic autopsies: a brief overview of virtual autopsy and its practice in the. J Healthcare Sci. 2023;3(12):624-30.
61. Bernitz H, Kloppers B. Comparison microscope identification of a cheese bitemark. J Forensic Odonto-Stomatol. 2002;20(1):13-6.
62. Rawson R. Computers in forensic dentistry. J California Dent Assoc. 1996;24(5):58-61.
63. Anuja P, Doggalli N. Software in forensic odontology. Indian J Multidisciplinary Dentistry. 2018;8(2):94-100.
64. Devi P, Thimmarasa V, Mehrotra V, Singla V. Automated dental identification system: An aid to forensic odontology. J Indian Acad Oral Med Radiol. 2011;23(1):S360-S4.
65. Patel J, Singh H, Paresh M, Verma C. Forensic odontology in the era of computer and technology. Int J Med Dent Sci. 2013;59-64.
66. Gustafson G. Age determinations on teeth. J Am Dent Assoc. 1950;41(1):45-54.
67. Condon K, Charles DK, Cheverud JM, Buikstra JE. Cementum annulation and age determination in Homo sapiens. II. Estimates and accuracy. Am J Physical Anthropol. 1986;71(3):321-30.
68. Grabherr S, Cooper C, Ulrich-Bochsler S. Estimation of sex and age of “virtual skeletons”–a feasibility study. Eur Radiol. 2009;19:419-29.
69. Murakami H, Yamamoto Y, Yoshitome K. Forensic study of sex determination using PCR on teeth samples. Acta Medica Okayama. 2000;54(1):21-32.

Cite this article as: Zahrani AA. Current trends in the methods of identification in forensic dentistry: a review of literature. Int J Community Med Public Health 2024;11:2468-75.