Review Article

Digitization in forensic odontology: A paradigm shift in forensic investigations

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Abstract

Forensic dentistry deals with proper handling, examination, and evaluation of dental records, which are then presented in the interest of law for justice. It plays a major role in identification of deceased individuals who cannot be identified visually or by other means after mass disasters or crimes. Digital forensics has revolutionized the traditional forensic investigations in terms of acquisition, analysis, and reporting of forensic evidence and its application is becoming common in the mass disasters, earthquakes, and terrorism. Sophistication of software and advent of digital technologies such as computers, computer-aided design computer-aided manufacturing systems, digital records, facial reconstruction, touch-free autopsy, and virtopsy has resulted in quick identification and extraction of a large amount of data with reduced sampling bias. This paper focuses on the evolution of forensic dentistry for effective detection and resolution of medico-legal matters and also highlights the use of comparison microscopes and new robotic tools by few forensic laboratories for automation of deoxyribonucleic acid sampling processes for human identification.

Key words: Digital, forensics, identification, technology, three-dimensional

Introduction

Forensic dentistry has become an integral part of forensic science that plays a major role in identification of deceased individuals who cannot be identified visually or by other means after. Examination and evaluation of dental records which are then presented in the interest of law for justice.[1] Identification is not an easy task in medicolegal cases in which answers by individuals are misleading or inaccurate to arrive at proper conclusion.[2] Digital forensics has replaced the traditional forensic investigations in terms of acquisition, analysis, and reporting of forensic evidence.

Access this article online	
Website: www.jfds.org	Quick Response Code
DOI: 10.4103/jfo.jfds_55_19	

Computers are used for committing cybercrime, and thanks to the burgeoning science of digital evidence forensics, law enforcement now use computers to fight crime. Earlier digital forensics only encompassed personal computers for crime investigation, but nowadays, computers are connected to local network, i.e., internet, so this field has expanded to include network forensics as well.[3]

Digital forensics could be defined as "application of computer science and investigative procedures for a legal purpose involving the analysis of digital evidence."[3]

How to cite this article: 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;11:5-10.

Due to software advancements and uncovering of root cause, the application of digital forensic investigations is increasingly becoming more common, especially in mass disasters such as terrorism, aviation, tsunamis, and earthquake. Besides this, dental radiographs play an integral role in identification and age estimation by comparison of antemortem (AM) with postmortem (PM) data after tentative identification of suspect. In the modern era, digital radiographs have considerably reduced the errors in interpretation or incorrect identification as with conventional radiographs.[4] Digital information has also made possible the communication with the odontologist easier in cases where the records are from overseas, and this reduces the troublesome problems which may come in medicolegal cases at later stages. This paper will discuss the need and application of various software technologies in crime investigations and how the digital evidence has revolutionized the traditional forensic investigations by solving forensic problems in a reliable and effective way.

Digital Dental Records

Digital dental records or dental chart is an official document that contains all the patient-related information such as history of present illness, clinical examination, diagnosis, treatment done, and prognosis.[5,6] Dentists should possess adequate knowledge and awareness regarding the maintenance of records for future use in various legal circumstances as incompletely filled records could result improper person identification by dental means. In developing countries like India, standard dental chart relies on visual interpretation of hand-drawn representation of dental conditions, i.e., odontogram is commonly used by the dentists.[5] Recently, digital dental chart (DCC), a new style of dental chart, has been introduced that is constructed using actual oral digital images and dental data, easy to upload on the internet website. It provides a large volume of information and reproduces dental conditions very clearly in detail on a cost-effective basis. Preserved digital evidence plays pivotal role in-person identification, especially in disaster victim identification (DVI) in which number of victims are large, bodies are disfigured or mutilated beyond recognization, and dental tissues are only available source for victim identification. It is a multidisciplinary process in which numerous people of different nationalities work together to collate information.[6] Literature has well-revealed uniqueness of individual dental tissues and their resistance to high temperatures, humidity, and pressure changes that makes them as a reliable source in the identification process.[7] The DVI guide Interpol 2009 states that accurate positive identification may be possible when the PM and AM dental records are of the same person. These records are a matter of professional confidentiality between the dentist and patient, and all the entries of an Interpol should be done by the dentist personally. Data should be electronically saved in the computer for at least 7–10 years. Computerized software enables a rapid comparison of AM and PM records of deceased victims in cases of mass disasters, earthquakes, terrorism, etc., In addition, software also allows superimposition and comparison of digital radiographs and photographs of the deceased person.[8] In coming decades, these internet-based dental charts will form a useful source of evidence in personal identification of bodies.[6]

Digital Forensic Radiography

Radiographs are one of the main sources of antemortem evidence, these are important in comparing consolidated antemortem with PM information, for example, the comparison of PM periapical radiographs of skeletal remains to antemortem panoramic radiographs of a missing person. Digital radiographs have revolutionized the forensic investigations which are used by the radiologists in large hospital settings for quick and accurate identification of mass causality victims along with internet-based DCC. In these situations, conventional methods of exposing the radiographs and then manually comparing them to dental records are time-consuming and cumbersome process. Digital radiography is highly advantageous as it allows immediate display of images on the computer screen that can be enhanced for optimal viewing and side-to-side comparison of antemortem and PM radiographs is possible with improved image quality thus accelerating the identification process.[9] They also play a role in on-site identification cases in which bodies are burned out or severely mutilated. Satellite communication allows digital transmission of images to the command center without loss of image details.[10]

Lewis and Senn, in his article, have well documented that "The practicality and flexibility of digital radiography and digital photography greatly facilitate the forensic comparison process. In mass disaster identification situations, digital radiography becomes much more useful than conventional radiography."[11] Furthermore, PM scanning time is reduced by the advanced imaging modalities such as multislice computed tomography (CT), three-dimensional (3D) cone-beam CT, and Dentascan. These modalities also allow clear differentiation of enamel, dentin, pulp, alveolar bone, and restorations.[9,10] Dentists have suggested difficulty in the orientation of PM intraoral digital sensors in the mouth of the body due to rigor mortis affecting the mandibular muscles. To overcome this problem, balloon catheters which can be inflated in the oral cavity are used to hold the sensor in position during exposure.[9]

Digital Photography

Photography is the best method to collect and preserve evidence in forensic cases, especially in the cases of human

abuse and bite mark analysis. The accurate photographic documentation of the injury is crucial as these provide a permanent record of injury to the victims, and comparative analysis of the suspect's dentition to the bite depends on the exact capture of bite mark injury of the victim.[12,13] Digital cameras capture the image that is digitized by the sensor within the camera and converted into computerized image file. Images can be transferred to the computer, on which they are displayed, could be edited, e-mailed, or printed as desired. The digital photographic system allows quick recording, exact duplication of images, and immediate retakes could be made if required. Digital images are two types as follows: (i) bitmapped images in the form of JPEG, PNG, TIFF, GIF, and BMP and (ii) vector-based images produced in "pain in draw" or "illustration" programs that mainly focus on manipulation or enhancement of images.[12]

Digital photography has improved the accuracy of bite mark analysis. Standard technique of photographic recording of bite marks includes proper orientation shots showing location of bite mark, macrophotography, proper angulation of the lens of the camera with the plane of injury and inclusion of ABFO #2 scale to determine photographic distortion, if present, is corrected later on by use of imaging software, namely, Adobe Photoshop.[12] Visible light photography is the most common method for the documentation of bite marks and photographic image, in which visible light on striking the skin exhibits four phenomena, i.e., reflection, absorption, fluorescence, and diffusion and the captured image display the combination of these phenomena. Recently, nonvisible photography that includes infrared and ultraviolet light has been introduced for enhancement of the appearance of injury in cases of disruption of skin, and it records the details of bitemark injury on the skin that appears completely healed under visible light. The surface of the skin and the subepithelial surface are severely damaged due to biting resulting in subdermal hemorrhage. The resultant by-products of blood hemoglobin and melanin migrate to the surface as the wound heals. The increased absorption and less reflection of nonvisible light occur due to increased melanin on the surface, thus enhancing the appearance of injury pattern. In fluorescent or alternate light imaging, injured tissue will fluorescence more in comparison to healthy tissue.[13] Digital photographic techniques have revolutionized the conventional ways of capturing image. For proper selection and utilization of the photographic technique, practitioner needs proper understanding of the photographic process and the computer technology.

Intraoral Three-Dimensional Optical Scanners

The direct and indirect scanning of the dental arch by the use of intraoral scanners has significantly improved the accuracy of bite mark impressions.[14] 3D-contact (point to point or linear) scanners analyses the surface of the object by the use of probe with a hard steel or sapphire tip. The main limitation is a longer time to conduct point to point scanning, it requires physical contact with the object, and it becomes difficult to scan concave surfaces. To overcome this, laser or optical scanners could be used that emits the laser light to scan the surface of the object, i.e., occlusal details of the teeth in the dental arch. The images captured by the sensor is further processed by the scanning software that generates multiple point clouds at different positions, which are then triangulated to create a 3D-surface model. These 3D images can be compared against available bite mark evidence, i.e., impression or photograph.[15] Intraoral 3D scanners have precluded the use of impression trays and material that usually result in patient discomfort and provide reliable, rapid, and noninvasive analysis of bite mark evidence.[16]

Computer-Assisted Overlays in Bite Mark Analysis

Comparison of suspect's dentition to a bite mark injury using overlays is done by several methods hand traced, photocopying, and recent computer-assisted overlay generation method is found to be the most reliable and accurate in comparison to other methods which also result in lot of observer bias.[17] In the manual method, alginate impression of the maxillary and mandibular arches of the suspect is taken, and dentition casts are prepared using dental stone. Then, transparent acetate sheet is directly placed over the biting edges of the dental cast, and then perimeter of biting surfaces are traced by fine black-tipped marker. Biting edges of maxillary and mandibular dental casts are traced separately in a horseshoe shape pattern. In computer-assisted method, dental casts are first scanned with biting edges on the glass plate of the scanner. The images are then opened on a computer by Adobe Photoshop software and gradual selection of biting edges is done by Magical Wand Selection Tool. The outlines of the biting edges are reproduced, and overlay is finally generated.[18] The biting edges of overlays of suspects dentition are compared to bite mark injury based on the matching criteria, scoring is done: no matching 0 score, slight score 1, moderate score 2, and excellent matching was given score 3.[18,19] Recently, new software "Dental Print" (2004, Granada, Spain) generates comparison overlays from 3D images of suspects dental cast. These overlays are more accurate, and it is difficult to manipulate 3D images by third person. In coming decades, these computer-based methods, especially newly introduced Dental Print 3D software will ease the bite mark analysis in more sophisticated manner reducing the chances of manipulation and errors.[18]

Computerized Facial Reconstruction

Facial reconstruction is a forensic tool that involves recognization of a skull accidentally found in forest, mass

disasters, etc., for the positive identification of an individual. It is an alternative process where no evidence is available, and the face of the unknown body is severely mutilated by animals, physical attacks, etc., to such an extent that even digital photography could not establish the identity.[20] Earlier researchers found difficult to believe that facial appearance is dependent on the skull morphology, and this lead to the emergence of two schools of thought. Some researchers prefer the term "facial approximation," i.e., various facial features could be reproduced from the same skull whereas other thought that face and the skull are directly linked to one another, and each single skull will reproduce only one face for the recognization of an individual, so they preferred the term "facial reconstruction" which is combination of both scientific methods and artistic skills.[21]

Facial reconstruction techniques could be both 2D and 3D, which are carried out and analyzed by various manual and computerized methods. The manual 3D facial reconstruction is done using clay, plastic, or wax directly on to the victims skull, tissue depth markers that represent soft-tissue depths are inserted on to the small holes on the skull cast at specific points, and finally reconstruction is done by three methods (i) anthropometrical American Method or Tissue depth method developed by Krogman in 1946, commonly used by law enforcement agencies and fine measurements are obtained by the use of needles, X rays, or ultrasound. As facial muscles are recorded in proper anatomical manner, this method requires highly trained personnel so is not used nowadays; (ii) Anatomical Russian Method developed by Gerasimov in 1971. In this method, facial reconstruction is done by shaping muscles, glands, and cartilage onto the skull layer-by-layer. This technique is much slower than the American method and requires high level of anatomical knowledge, so it is not commonly used; (iii) combination Manchester or British method was developed by Neave in 1971. It is the most accepted manual method and takes both soft-tissue thickness and adjacent facial muscles into consideration. Once the cranium and mandible are articulated, and the skull is mounted on an adjustable stand in the Frankfort horizontal plane, facial tissue pegs or markers are then added on the skull, either by placing them directly on the skull or by inserting them on previously drilled holes on the cast at 90° using a 3-mm drill bit. Each peg length represents the mean tissue depth at the anatomical point. Musculature is usually reconstructed in clay and modeled on to the skull to create a finished face.[21,22]

Software advancement has led to the development of computerized 3D-facial reconstruction systems to recreate characteristic facial morphology dependent on the skeletal features. The skull is first digitized using a laser scanner, and a video camera interfaced to a computer, forming a fully shaded 3D surface. Various markers indicating the tissue depths are then placed on different selected sites on the skull. Some computerized systems employ 3D-animated software whereas few model face onto the skull by virtual sculpture systems with haptic feedback which has the advantage of being able to feel surface of the skull, provide important surface details for facial reconstruction such as muscle attachment strength, position of eye, and position of malar tubercle.[20,21] Computerized systems are more rapid, easier, efficient, and cost-effective than manual reconstruction methods. It decreases practitioners subjectivity and skill, recreates multiple images of the same face efficiently, and provides realistic facial appearance simulating photographs.[22]

Virtopsy/Virtual Autopsy

An autopsy or PM examination is a surgical procedure that consists of a thorough examination of a corpse to determine the cause and manner of death and evaluation of any injury that may be present. The progress in imagistic modalities has changed the face of conventional autopsies into a scalpel free autopsy, virtual autopsy or "virtopsy."[23] Advanced modalities such as CT and/or magnetic resonance imaging (MRI) scan the dead bodies and provide a more sensitive, specific, and accurate results than that of the conventional autopsy. Virtopsy is accomplished by placement of markers on the surface of the body by the help of Virtibot, and then, surface scan of the corpse is done by the use of stereoscopic cameras of resolution 0.02 mm to create a 3D-color image in 10 s. After the surface scan, the body is subjected to CT, MRI, and magnetic resonance spectroscopy (MRS) scans and data is finally fed to the computer where displayed images could be manipulated , rotated at various angles; and density differences of variable color are assigned to soft tissues and bones for easy interpretation such as blue for air pockets, beige for soft tissues, red for blood vessels, and white for bones.[23,24]

MRS is a recent technique in virtopsy that determines the relative concentration of various metabolites in the tissues, thus useful in estimating the time of death. MR microscopy is a microimaging technique which is used to study the soft-tissue injuries like retinal hemorrhage, electric injury to the skin, etc., and microtomography is used to study the weapon involved and its injury patterns.[25] Virtopsy offers numerous advantages such as archives can be easily retrieved for medicolegal purposes, toxins are easily examined without contamination in case of death due to drug abuse and fracture lines, primary and secondary traumas, depth of foreign body could be effectively assessed in comparison to conventional autopsy. Although it has innumerable advantages, the major drawback is physiological senses of a pathologist such as smell, texture, and color are restricted as there is no direct contact with the dead body of the victim, and technique is expensive for low developing countries. This technique should be

used as an alternative to traditional autopsy procedures for noninvasive, better, and quick examination of the dead body. Moreover, it respects the religious beliefs of people or communities who believe that body and soul are inseparable and forbid autopsy.[25,26]

Three-Dimensional Printing

In the digital world, the use of 3D printing in investigative or court purposes is relatively a new technique. It has taken forensic investigations to a new level that quickly generates physical replica of object from computerized data. CT images are commonly used for 3D printing due to relative ease of image postprocessing.[25] Anthropological skulls are scanned using CT and image sections are reconstructed with isotropic voxels of 1.25 mm or less. As 3D printers do not accept DICOM images, standard tessellation language (STL) file format is used that defines the surfaces as collection of triangles, triangular facets that fit together like a jigsaw puzzle. DICOM images are manipulated by specialized 3D computer-aided manufacturing software (CAD) that involves segmentation of desired tissues by placing region of interest (ROI) around them and then refining the STL representation of the ensemble surface defined by these ROI. When the manipulation and refining are complete, data in STL file format are transferred to 3D printers that fuse successive 3D layers of the object. This technique is also known as "additive layer printing" as CT slices are printed sequentially as 2D layers which can be arranged or fused together to create the 3D-colored models representing anatomic structures. The final models are anatomically accurate, easy to understand as they create colored representations of bone, blood vessels, and soft tissues.[26,27]

3D printing has wide forensic applications, which include bite-mark analysis, palatoscopy, cheiloscopy, tongue print pattern analysis, facial reconstruction, sex determination age estimation and illustrates pattern of bone injury. They are very helpful in solving crime cases and presentation of evidence to court. The costs are decreasing as this technology is used by various fields; and new software with better resolution are on the way for better utilization of this technology.[27]

Forensic Thanatology

Forensic thanatology is investigation of every phenomenon related to death and is performed mainly by cadaveric examinations. Pink tooth phenomenon (PTH) is an uncommon autopsy finding that comprises of pinkish or reddish discoloration of tooth due to the penetration of hemoglobin into the dentinal tubules that is saturated with carbon dioxide. It does not exactly rule out the cause of the death but is sole expression of cadaveric decomposition. In accidental cases that result in cranioencephalic trauma, asphyxia, etc., victims are usually in advanced stages of decomposition, and PTH is detected in most of the teeth. Therefore, forensic odontologists should be aware of the PTH phenomenon for accurate PM examination.[28]

Forensic Comparison Microscopes

Forensic comparison microscopes are very helpful in the criminal investigations and allow better comparison of two images, i.e., studies known sample against collected evidence. It consists of two compound microscopes that are placed side to side and allows the forensic expert to view both the samples through the center eye piece. It employs digital camera system to view and simultaneously compare both the images to see whether they are identical or different. In addition, multiple lenses are present to magnify the images which are finally transferred to the computer monitor or LED screen. These are highly beneficial for the forensic experts as they do not have to rely on the memory when comparing two images as with conventional microscope.[3]

Forensic BioRobots

It is well documented that deoxyribonucleic acid (DNA) is a reliable source for human identification, and use in criminal investigations has rapidly grown in recent years. Forensic robots have helped laboratories for automation of DNA sampling process that involves extraction, quantification, and dilution. Parys Proszek *et al*. found BioRobot M 48 to be very effective for DNA extractions from most specimens in most forensic laboratories. These primarily aim at improving efficiency and enable the forensic scientist to focus on analysis and interpretation rather than on processing tasks. Thus, they save the time by speeding up the DNA profiling process and also reduce the human errors.[3,29]

Conclusion

Advancements in the technology have opened up new directions to solve criminal and civil cases. Digital forensics has revolutionized the traditional forensic investigations in terms of collection and analysis of data. Moreover, computerized images are more reliable, accurate with fewer errors and could not be manipulated by the third person. These technologies are very helpful in DVI in which innumerable bodies are severely mutilated and allow digital transfer of the images without loss of information. For better forensic investigations, there is a need for practice and implementation of the software in an effective and legal way. In coming years, digital forensics will become an integral part of forensic investigative process and reduced costs of technology will enhance their utilization by various specialties.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Afify MM, Zayet MK, Mahmoud NF, Ragab AR. Age estimation from pulp/tooth area ration in three mandibular teeth by panoramic radiographs: Study of an Egyptian sample. J Forensic Res 2014;5:1-5.
2. Parimala D, Daniel MJ, Srinivasan SV, Kumaran JV. Analysis of time-dependent changes in bitemarks on Styrofoam sheets. Contemp Clin Dent 2015;6:S77-80.
3. Rawson RD. Computers in forensic dentistry. J Calif Dent Assoc 1996;24:58-61.
4. Manigandan T, Sumathy C, Elumalai M, Sathasivasubramanian S, Kannan A. Forensic radiology in dentistry. J Pharm Bioallied Sci 2015;7:S260-4.
5. American Academy of Pediatric Dentistry. Guideline on record keeping. Pediatr Dent 2004;34:132-6.
6. Hanaoka Y, Ueno A, Tsuzuki T, Kajiwara M, Minaguchi K, Sato Y. Proposal for internet-based digital dental chart for personal dental identification in forensics. Forensic Sci Int 2007;168:57-60.
7. Fereira JL, Fereira AE, Ortega AI. Methods for the analysis of hard dental tissues exposed to high temperatures. Forensic Sci Int 2008;178:119-24.
8. Shanbhag VK. Significance of dental records in personal identification in forensic sciences. J Forensic Sci Med 2016;2:39-43.
9. Chiam SL. A note on digital dental radiography in forensic odontology. J Forensic Dent Sci 2014;6:197-201.
10. Campobasso CP, Dell'Erba AS, Belviso M, Di Vella G. Craniofacial identification by comparison of antemortem and postmortem radiographs: Two case reports dealing with burnt bodies. Am J Forensic Med Pathol 2007;28:182-6.
11. Lewis JM, Senn DR. Forensic dental age estimation: An overview. J Calif Dent Assoc 2015;43:315-9.
12. Balaji N, Senapati S, Sumathi MK. Forensic digital photography: A review. Int J Dent Med Res 2014;1:132-5.
13. Wright FD, Golden GS. The use of full spectrum digital photography for evidence collection and preservation in cases involving forensic odontology. Forensic Sci Int 2010;201:59-67.
14. Maji A, Khaitan T, Sinha R, Sarkar S, Verma P, Shukla AK. A novel computer-assisted method of bite mark analysis for gender determination. J Environ Public Health 2018;2018:7130876.
15. Zimmermann M, Mehl A, Mörmann WH, Reich S. Intraoral scanning systems – A current overview. Int J Comput Dent 2015;18:101-29.
16. Aragón ML, Pontes LF, Bichara LM, Flores-Mir C, Normando D. Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: A systematic review. Eur J Orthod 2016;38:429-34.
17. McNamee AH, Sweet D, Pretty I. A comparative reliability analysis of computer-generated bitemark overlays. J Forensic Sci 2005;50:400-5.
18. Khatri M, Daniel MJ, Srinivasan SV. A comparative study of overlay generation methods in bite mark analysis. J Forensic Dent Sci 2013;5:16-21.
19. Tuceryan M, Li F, Blitzer HL, Parks ET, Platt JA. A framework for estimating probability of a match in forensic bite mark identification. J Forensic Sci 2011;56 Suppl 1:S83-9.
20. Lee WJ, Wilkinson CM, Hwang HS. An accuracy assessment of forensic computerized facial reconstruction employing cone-beam computed tomography from live subjects. J Forensic Sci 2012;57:318-27.
21. Wilkinson C. Facial reconstruction – Anatomical art or artistic anatomy? J Anat 2010;216:235-50.
22. Vanezis P, Blowes RW, Linney AD, Tan AC, Richards R, Neave R. Application of 3-D computer graphics for facial reconstruction and comparison with sculpting techniques. Forensic Sci Int 1989;42:69-84.
23. Badam RK, Sownetha T, Babu DB, Waghray S, Reddy L, Garlapati K, *et al.* Virtopsy: Touch-free autopsy. J Forensic Dent Sci 2017;9:42.
24. Yogish P, Yogish A. Virtopsy: New phase in forensic odontology. Int J Dent Health Sci 2015;2:1548-5.
25. Joseph TI, Girish KL, Sathyan P, Kiran MS, Vidya S. Virtopsy: An integration of forensic science and imageology. J Forensic Dent Sci 2017;9:111-4.
26. Chaudhary RK, Doggali N, Chandrakant HV, Patil K. Current and evolving applications of three – Dimensional printing in forensic odontology: A review. Int J Forensic Odontol 2018;3:59-65.
27. Ebert LC, Thali MJ, Ross S. Getting in touch–3D printing in forensic imaging. Forensic Sci Int 2011;211:e1-6.
28. Franco A, Mendes SD, Picoli FF, Rodrigues LG, Silva RF. Forensic thanatology and the pink tooth phenomenon: From the lack of relation with the cause of death to a potential evidence of cadaveric decomposition in dental autopsies – Case series. Forensic Sci Int 2018;291:e8-12.
29. Parys Proszek A, Branicki W, Wolanska-Nowak P, Kupeic T. Application of biorobot M48 to forensic DNA extraction. Forensic Sci Int 2008;1:58-9.