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RESEARCH ARTICLE

ADVANCED TECHNOLOGIES AN AID IN FORENSIC ODONTOLOGY. AN UPDATE

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Abstract

Forensic dentistry plays a major role in the identification of those individuals who cannot be identified visually or by other means. Advance technologies available have made the investigation by forensic experts much faster and more accurate. This article briefs an overview of recent advanced technologies available in the field of forensic odontology.

INTRODUCTION

Forensic Odontology, or forensic dentistry, was defined by Keiser-Neilson in 1970 as; "that branch of forensic medicine which in the interest of justice deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of the dental findings".(Verma et al, 2014) Forensic Odontology is a relatively new science that utilizes the dentist's knowledge to serve the judicial system. Dentists qualified in forensic science are giving expert opinion in cases related to human identification, bite-mark analysis, craniofacial trauma and malpractice. Human identification relies on the quality of dental records; however forensic odontologists can still contribute to the investigation in the absence of dental records through profiling the deceased person using features related to teeth and other oral structures. (Al- Amad, 2009)

Human identity is the mainstay of civilization, and the identification of unknown individuals always has been very important to the society. Not only is it important to identify the deceased to ensure appropriate obsequies, but also there are issues such as criminal investigations, insurance settlements, and military proceedings that can be resolved only with a positive identification. The identification of a missing individual can aid tremendously in the process of grief resolution of the family and friends. (Verma et al, 2014)

The natural teeth are the most durable organs in humans, and understanding their past and evolution, relies heavily upon remnants of dental evidences available. (Gupta et al., 2014) Teeth can persist long after other skeletal structures have succumbed to organic decay or destruction by fire. (Gupta et al., 2014) Hence the significance of Forensic odontology lies in its application in various circumstances such as-

- Identification of found human remains
- Identification in mass fatalities
- Identification of victims of air and industrial accidents
- Identification in natural disasters
- Identification in terrorist attacks
- Assessment of bite mark injuries
- Assessment of cases of abuse (Child, spousal, elderly) & domestic violence

- Civil cases involving malpractice
- Identification by age and gender
- Identification in cases of human stampede

The roles of any forensic scientist are to collect, preserve and interpret trace evidence, then to relay the results to the judicial authority in a form of a report. Those functions require sound knowledge in dealing with crime scenes and sufficient acquaintance in law. (Al- Amad, 2009) Mass disaster and medico legal cases create a big problem in today's society. With the increasing rate and complexity of crime, it's becoming more difficult for the collection of feasible and suitable evidence and appropriate comparison methods. Also there has been incredible research that has led to technological advancements in forensic odontology on a global scale.(Rai and Kaur, 2013) Advances in photographic, radiographic, and computer technology have provided the forensic dental team with additional resources to enable recovery, documentation, storage, and comparison of forensic dental evidences. (Chandra et al., 2010) Advance technologies available have made the investigation by forensic experts much faster and more accurate than early times. This review highlights the various advance technologies available to date that can assist forensic odontologists in investigation.

ADVANCES TECHNOLOGIES IN FORENSIC ODONTOLOGY

Portable Dental X-ray Generator

In recent years, the advance in obtaining postmortem radiographs has led to the invention of NOMAD ™ hand held, battery powered X- ray device. The Aribex™ NOMAD™ portable hand-held dental radiation emitting device was developed in 2004 and received FDA approval as a medical device in July, 2005 and has been used extensively and almost exclusively in the resolution of mass fatality incidents (MFIs) requiring forensic dental identification of numerous victims. (Danforth et al., 2009) NOMAD™ (Aribex, Orem, UT) offers hand-held portability in X-ray technology, featuring cordless operation, rechargeable 14.4 V nickel–cadmium battery packs, and provides more than 100–700 exposures on a single charge. It weighs 8 pounds, has internal lead shielding and an external lead–acrylic backscatter shield. There is an automatic shut off and ''Enable'' feature that minimizes the risk of inadvertent exposure. The NOMAD™ uses direct current, operates at a fixed 60 kV, 2.3 mA and has a 0.4 mm focal spot with a 20 cm source-to-skin distance.(Goden et al., 2008). The NOMAD™ is easy to set up and use. It meets radiation safety standards and does not require personal dosimetry. NOMAD™ presents no risk to the patient or to the operator and the measured doses are well below recommended levels. The image quality of the radiographs is equivalent to that produced with standard X-ray equipment. (Goden et al., 2008) The important concern when using portable X- ray machine is the backscattered radiation exposure. Few of the studies recommend to select the X-ray machine attached with a backscatter shield and use a longer cone, and to wear the lead gloves.(Cho and Han, 2012)The newest version is the NOMAD PRO™. It has improved shield to prevent radiation leakage. It has smaller design and weighs 5.5 pounds. It also has an additional lock mechanism that prohibits its use by unauthorized personnel.(Berman et al., 2013)The device, like most x-radiation devices is safe when used according to manufacturer's instructions. It is important that in a multiple fatality situation or in forensic case work that both the operator and any assistants obey simple rules of radiation hygiene as well as manufacturer's instructions. (Wood and Mawdsley, 2011)

Digital Photography

Forensic photography is the art of producing a defined reproduction of a crime scene or an accident scene for the benefit of a court or to aid in the investigation.(Bernstein, 1983) Digital cameras currently provide an easy and quick method of recording images and various types of cameras are been employed to do so. (Rowan et al., 2010) Full spectrum forensic photography is very important in cases involving dental identification, human abuse and bite marks. (Wright and Golden, 2010) In dental identification, it may be necessary to take ultraviolet (UV) photographs of loose teeth found in skeletonized remains to determine whether or not tool marks can be seen on the surface of the loose teeth indicating a non-natural avulsion. Similarly, in human abuse or bite-mark cases it may be advantageous to use alternate light imaging (ALI) photography to document injuries to the skin that are not visible to the naked eye. Infrared (IR) photographs can be useful to locate and document bleeding below the surface of the skin or to enhance detail of tattoos in decomposing or mummified skin. In all cases, the investigator should take typical visible light photographs, as well as employ special non-visible spectrum photographic techniques, so that the images are captured using the full spectrum of light. (Wright and Golden, 2010)

The inherent efficiencies of digital photography make it extremely beneficial; however, the practitioner needs a basic understanding of computer technology and standard photography for proper utilization. (Balaji et al., 2014)

Digital Radiography

Digital dental radiography is becoming more popular in dental practice. The reason is due to advantages it offers such as lower exposure to radiation, ease of storing of images, and elimination of chemical processing. (Chiam, 2014)

Digital radiography requires the use of conventional X- ray source such as 70KvP x ray machine capable of 1/100 second exposure. There are three types of direct radiography such as

I) Digitizing after (film) development (DAD), this methodology requires normal film exposure and scanning of the processed film into the computer.

II) Phosphor dental radiography, this methodology uses phosphor substrate in the shape of a radiographic film

III) Direct digital X- ray, utilizes sensor sized and shaped like a radiographic film. It is made up of scintillation screen and a charge-coupled device (CCD) or complementary metal oxide semiconductor (CMOS). When energized by radiation, this device creates a direct image on the pixels of its charge-coupled device (CCD) or complementary metal oxide semiconductor (CMOS).This radiographic image is then sent to a computer through wire or wireless technology. Thus because of its ability to save time, it is recommended for use in clinical and forensic cases. (Herschaft et al, 2007)

Cone Beamed Computed Tomography (CBCT)

Cone-beam computed tomography (CBCT) is a relatively new imaging technique. The introduction of dentomaxillofacial CBCT scanners in the late 1990s has led to interest in using these devices in the field of dentistry. (Jawaid et al., 2014) This imaging technique is based on a cone-shaped X-ray beam centered on a 2-D detector that performs one rotation around the object, producing a series of 2-D images. These images are re-constructed in 3-D using a modification of the original cone-beam algorithm. (Almari et al., 2012) Software programs incorporating sophisticated algorithms including back - filtered projection are applied to these image data to generate a 3D volumetric data set, which can be used to provide primary reconstruction images in 3 orthogonal planes (axial, sagittal and coronal). (Alok et al., 2014) CBCT differs from CT (Computed Tomography) in that it uses a single X-ray source that produces a cone beam of radiation (rather than a fan beam, as with CT), hence low dose. (AlJehani, 2014)

CBCT may be very useful in some forensic procedures, offering several advantages for pre-mortem forensic and post-mortem forensic imaging including good resolution for skeletal imaging, relatively low cost, portability, and simplicity. It provides a noninvasive alternative for age estimation which is an important aspect of forensic dentistry. (Jawaid et al., 2014) Age predictions are also possible using pulp/tooth volume ratio measurements (of mandibular canines) from Cone Beam Computed Tomography. (Jagannathan et al., 2011) Sexual dimorphism can be evaluated by using anthropometric measurements on mandibular images obtained by CBCT. (Jawaid et al., 2014)

Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM/EDS) and X-ray Fluorescence spectrometer (XRF)

Victim identification through dental records may be the preferred method for determining identity when a victim is decomposed, disarticulated, or incinerated. The dentition represents one of the most resilient structures in the human body and can survive extreme conditions. It is also an excellent source of distinction among individuals. The combinations of restored, nonrestored, missing, and decayed teeth can be as unique as a fingerprint as the probability of two dentitions being the same is very low. It is this uniqueness that allows for dental comparison to be a legally acceptable means of identification. (Bush et al., 2007)

Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM/EDS) and X-ray fluorescence spectrometer (XRF) has been recently be utilized to determine the location of resins within the dentition as well as the brand of the resin based on elemental composition in cremated and non-cremated individuals. In both SEM/EDS and XRF, characteristic X-ray emissions are excited by an energetic source. The main difference between the techniques is the type of radiation used to excite the emissions. In SEM/EDS, it is an electron beam, whereas in XRF, an X-ray beam excites the characteristic X-rays. Spectroscopy in both cases consists of measuring the energy of the emitted X-ray peaks, forming a spectrum that represents an elemental fingerprint of the sample. In XRF, because an X-ray source is used, the spectral background is lower, allowing small peaks to be recognized. This results in the ability to detect very low concentrations of an element. (Bush et al., 2007) One of the advantages of XRF is the ability to detect major, minor, and trace levels of an element, whereas EDS is limited to major and minor elemental concentrations. (Bush et al., 2008)

Restorative resins are principally composed of an organic matrix surrounding inorganic filler particles. The inorganic fillers are added mainly for physical properties and radiopacity purposes. The radiopacity range is greater than or equal to that of enamel. Heavy elements, such as Sr, Ba, Zr, and Yb are incorporated in unique combinations to match the radiopacity of enamel. It is these inorganic elemental combinations that remain unchanged even after exposure to cremation conditions and allow for the distinction between brands or brand groups. (Bush et al., 2008) Thus XRF has the ability to detect these elements even in very low concentrations. The only disadvantage of XRF is that light elements (in this case P and below in the periodic table) are not detectable due to absorption of low-energy X-rays by air and the detector window. Thus, some elements making up the tooth and bone structure (P, O) are not detectable. This also applies to the principal components of the resin fillers in which the elements Si and O are not detectable. The elements added to fillers for radiopacity, however, are readily detectable (Ba, Sr, Zr, and Yb), and the presence and combinations of these elements enable identification of resin brand.In addition to the dental records, thus if the restorative material brand can also be identified then it would be an additional variable for the investigator to be more certain in his conclusion on identification of the victim. The knowledge of restorative material brand can be a great asset in aiding identification. (Bush et al., 2007)

Computer Assisted Dental Identification Softwares

CAPMI

Computers have been used for many years by forensic odontologists for data collection and documentation of various evidences collected. The first application developed was Computer Assisted Post Mortem Identification (CAPMI), developedby Lorton, Langley and Weed in late 1980s. This program has been assisting forensic odontologists in identifying victims of mass disasters by producing possible matches. It was used by U.S Military on many mass disasters and by forensic odontologists for private sector. (Berman et al., 2013, Al-amad et al., 2007)

DVI System International

DVI (Disaster Victim Identification) System International is software that operates on the PC-Windows platform. It is capable of managing aspects of identification in case of mass disasters, where it has particular advantages when victims of several nationalities are involved. The forms consist of two sets of data sheets: a yellow form set for recording latest known data concerning a missing person; and a pink form set for recording all findings concerning a dead body. The yellow and pink forms have sections recording the same type of data: C forms contain technical descriptions on effects (clothing, jewellery, documents etc.); D forms contain physical characteristics; E forms contain medical information; F forms dental information; G form any further information that may assist in identification. It has an advantage of simultaneous display of comparable ante mortem and postmortem pages in the same window is performed as part of a Microsoft Office Word function, whereas similar display of digital photos and radiographs can be done as a part of Microsoft office picture manager function.(Torpet,2005)

WinID3

WinID was developed by Dr.James McGivney as a free computer –assisted dental identification application. This application was used in various mass disasters like terrorist attack on world trade center, Hurricanes Katrina etc.WinID3 uses intuitive algorithm that gives it the ability not only to sort for requested identifiers, but to compensate and not eliminate identifiers changes that have occurred due to reasonable and explainable differences references. For instance if a victim's particular tooth is not restored in ante mortem record and is reported to be restored in post mortem then it will not be eliminated from consideration because of the time lapse that allows for a possibility that it could have been restored later. WinID3 has been bridged with DEXIS, which is a digital radiography application for capture and management of dental radiographs and all other photographs and other documents. This allows WinID3 to combine dental charting with radiographic/photographic record for a seamless integrated system of case review and comparison. (Berman et al., 2013)

CONCLUSION

Advances in technology ensure the integration of various evidences available and has made comparison more easy and accurate in identification of victim in medico legal cases or in cases of mass disaster. The inherent efficiencies of various advanced aids available makes it extremely beneficial, however, the forensic expert needs a basic understanding of the techniques and principles of the various technologies for appropriate utilization of the aids during the investigation.

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