The Role of the Forensic Odontologist in Disaster Victim Identification: A Brief Review.

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ABSTRACT: Disaster Victim Identification (DVI) is a culmination of several individuals that include rescue teams, recovery teams, forensic pathologists, odontologists and anthropologists. All these personnel work collaboratively to bring together their respective fields to identifying victims in a disaster. Factors needing consideration after a disaster include the number of victims, condition of remains including the location of the disaster, acceptable scientific methods of identification, safe data collection and storage, presence of electrical grids, water supply and proper waste disposal arrangements. This review focuses the discussion on identification using dental evidence and the key learning's of the past and the future techniques that may be used to make the identification process easier and efficient in terms of manpower and technology.

Keywords: Disaster victim identification, DVI, Dental Identification, Dental Disaster Identification, Disaster victim identification using dental evidence

Introduction

Disasters are events that are often unexpected with damages of unexpected magnitudes. Disaster response and management has always been one of the biggest challenges to a community [1]. Disasters, especially man made cannot be predicted, but they frequently result in injuries and deaths of large numbers of people [2]. It can be safely said that disasters are such events that management of the human remains becomes impossible through normal mortuary functioning [3]. Victim Identification plays an important role after any disaster. Disaster Victim identification after disasters encompasses all the methods and the procedures used in the identification of deceased victims in events of mass disaster [4]. No two disasters are alike, hence the circumstances differ for investigations in different disasters for the DVI response teams [5]. In situations of mass fatalities, experts from several specialities are called in to assist in the quick identification and faster return of human remains of the deceased to their respective relatives. Identifying victims involved in disasters not only has religious and personal reasons attached to it, but it also has an important socio-legal influence [3, 6-9]. These cases may be simple or complex depending on the type of disaster. It becomes complex when the number of people involved in the disasters is higher or the location of the disaster is hard to approach [3]. Collection of Post Mortem data is often perplexed and its is even harder in mass disasters of a greater magnitude, such as the World Trade Center attack and Tsunami in 2004 [10].

Disaster victim identification can be broadly divided into five periods of activity. These periods cover the entire time between the occurrence of a disaster and the identification of the victim. They are broadly speaking; the scene, mortuary, collection of ante mortem data, reconciliation of data and debrief [4].

Under disaster conditions a sieving method of increasing complexity is applied to each victim and one of the three pathways are then following to bring about the identification. The three fundamental pathways are based on the level of body destruction; a visually identifiable body, decomposed victim (may be as a result of fire, natural decomposition, or significant trauma) or skeletal remains. Each of the three pathways requires a set of diagnostic steps [11] to be undertaken that are presented in Table 1.

Table 1: The methods used in the identification process are dependent on the level of body decomposition (3)

Visually Identifiable Body	Decomposed body	Skeletonized Remains
a) Photographs	a) Photographs	a) Photographs
b) Radiographs	b) Radiographs	b) Radiographs
c) Dental Charting	c) Dental Charting	c) Dental Charting
d) Dental Impressions	d) Stabilization and/or Preservation of Remains	d) Jaw articulation and Occlusal Analysis
e) Preservation of Oral Structures		e) Preservation of Remains [11]

Traditional methods involve the recovery of bodies, intact or otherwise and recording of fingerprints and dental and medical identification points. The nature of these disasters determines the amount of damage to the victim's body, thus requiring several techniques to aid in the identification of the individual. Identification by DNA analysis and a role of Forensic anthropology [12]. The primary aim of this short review is to highlight the significant role of forensic odontology in disaster victim identification. The review will examine the historical perspectives of forensic odontology in disaster victim identification and extend from this base to look at the evolution of science (and technology) in the field that now underpins best practice in odontology as it contributes to disaster victim identification.

History of identification using dental evidence

One of the earliest recorded cases of human identification using dental evidence dates back to the period of Emperor Nero. Around 66AD, Nero's love interest Sabina was killed by his wife's soldiers who identified the head of the victim by recognizing a black anterior tooth [13]. In India, the most likely first human identification using dental evidence was of M. Raja Jayachandra Rathore of Canouj, who had passed away in 1191 in a battle. He was identified based on his false anterior teeth.[13] The first case of identification using dental evidence that was accepted by the law was in the United States in 1849 [14]. Dr. Oscar Amoedo was the Professor at the Dental School in Paris, and is considered the father of Forensic Odontology. His involvement in the charity bazaar fire disaster in Paris in 1897 appears to be the first mass disaster case where victims were identified using dental evidence. More recently several thousand people lost their lives in the 9/11 attacks on the World Trade Centre in the United States of America. A number of these victims were identified using DNA extracts found in the victims tooth brushes [13].

Other major identification methodologies

Clearly, Forensic Odontology is part of a suite of techniques used to identify mass disaster victims. It would be remiss if we did not highlight the two major methods. Although, not specifically part of forensic odontology, clearly both interact with and are integral to a final positive identification system that has good sensitivity and specificity. DNA analysis has been identified as one of the chief modalities in the identification of disaster victims [15, 16] and has been successfully used in the past.[17] The main advantage of using DNA in an identification process is that it may be recovered from almost any biological material [18, 19]. Samples collected for matching may range from tooth-brushes, clothes, combs, among other personal items. In some instances comparing samples with that of immediate family members or first degree relatives is used [2]. Forensic anthropology may be defined as a field of science related to the examination of what is believed to be human remains [20]. Any disaster, irrespective of whether it is man-made or natural, is in all probability to cover an array of forces ranging from burning due to heat, or crushing or impact due to structure collapse, or an explosion or environmental factors like temperature ad humidity [4]. Forensic anthropologists assist in disaster victim identification by handling a number of differently preserved skeletal remains which includes examining human remains in diverse state of preservation, mummified or skeletonized remains, burns, dismembered or a combination of any of the above. Clearly, the robust nature of teeth makes them an integral part of the forensic anthropologist systematic approach to identification.

Dental Identification

Teeth, by their very nature are preserved through many physically damaging events and therefore can play an important role as remains for identification as they are resistant in nature [21, 22]. It is clearly an important role for forensic odontologists to be part of the

integrated DVI process. Dental identification in DVI may be described as the identification of people using available dental records and dental characteristics of the person by comparing findings observed from investigating ante-mortem and post-mortem records. Forensic odontologists must make a detailed and accurate report of findings such that thorough comparisons can be made between ante-mortem and post-mortem information [23]. Dental identification process involves a simple yet systemic series of processes. It is comparative in nature and may be acknowledged as an anthropological method with descriptive and biological proficiencies [24]. Forensic Odontology necessitates identification of available dental evidence, collection, examination, analysis and preservation of the collected evidence. It is vital that the data collected pass through strict quality management in order to facilitate accurate data interpretation to attain high standard results as anticipated by the Disaster Victim Identification instructing authority along with the parties involved.[24]

Dental examination in a Disaster Victim Identification process involves the collection and recording information on the condition of the jaws and teeth, specifically systematic analysis of the clinical status of each tooth, for example if it is sound, carious, filled. If teeth are missing then it should be noted if they were missing ante mortem or post mortem. Radiographs and photographs showing supplementary characters act as important tools in the identification process. Analysis of an individual's dental history may also point to some unique pathological states (e.g.: supernumerary tooth, impactions) that taken in composite with the other evidence can enhance the quality of identification [25]. Age estimation plays an important part in the identification of victims of a disaster, more so in cases of children with minimal or no dental work. Periapical radiographs showing the apices can be used in the age estimation. In some cases an intact tooth can be extracted to provide DNA samples from the protected pulp of the tooth [25]. Dental identification primarily relies on precise information of who were involved in the disaster, if they would have any dental records, and if they do how to access these records.[24] In summary forensic odontologists can play a number of strategic roles in the processes of a disaster victim identification investigation (Table 2).

Table 2: The key tasks for forensic odontologists involved during a disaster victim identification investigation:

Evidence collection:	The forensic odontologists can advice recovery of fragmented or complete jaws, teeth, any restorations or dental prosthesis that could have been dismembered from the body. The forensic odontologist can also advice on the documentation and safe transportation of the collected information.
Examination and Recording	It is the responsibility of the forensic odontologist to maintain occupational health and safety standards during examination and recording information. Strict quality control must be maintained during the process with special consideration towards cross contamination.
Interpretation	The forensic odontologist searches and compares collected data against available ante mortem data. Once the match is positive, the information and two experienced forensic odontologists who were not previously involved in the procedures must reexamine information gathered and the results to eliminate cross examiner errors.
Reporting	Reports on progress are important as potential inadequacies if any can be identified earlier in the process. This also helps maintain a record of occupational health and safety along with quality control.
Presentation	Standard formats for data presentation must be used (e.g: plassdata). This would furnish much needed accuracy, clear and factual summary of the collected and interpreted evidence, and also be used to conclude the identification process.
Protocols	It is crucial to follow a protocol in order to use, handle, store data and use information. This data can be used anytime in future for cross referencing if the situation demands it. [9, 11, 44]

In odontological investigations after disasters, dental charts and radiographs made available from the families of victims or their dentists are compared with the dental status of the victim to reach a positive identification [26]. Radiographs have been recommended [27]. and used in comparing ante mortem and post mortem information for a long time now [6]. Dental information gathered are then recorded in Ante-Mortem and Post Mortem data charts. Interpol or the International Criminal Police Organization has played an important role in DVI work for more than two decades. In 1984, the first DVI manual was published and is regularly updated and circulated among member countries [7]. Interpol has suggested the use of standard dental identification charts, both Ante-Mortem and Post-Mortem, in the identification procedures [23, 28]. The most recent Disaster Victim Identification forms can be found at Interpol website (http://www.interpol.int/INTERPOL-expertise/Forensics/DVI-Pages/Forms). Apart from paper forms, a number of digital software's have been used in the past to record Ante-Mortem and Post-Mortem information following a disaster [29]. However, Plassdata, a much newer software proposed by the Interpol has been in use for dental charting in disaster victim identification more recently [7, 30].

Role of Forensic Odontologists during disasters

Forensic odontologists in a disaster zone are involved in recognizing dental evidence, collecting, recording and analyzing them. A report is then prepared based on the findings analyzed by examining the dental and the surrounding anatomical structures [24]. In most countries, forensic odontologists are included in the disaster victim identification team [26]. This team is usually constituted of members from multi-disciplinary backgrounds, all dedicated to ascertain thorough management during a disaster All care is taken to ensure proper handling of evidence or information collected from a disaster site. To maintain the integrity of a disaster site, it is essential to collect and process evidence in a manner that accurate results can be achieved and in turn provide closure for families of those involved in the disaster. The principal duties of forensic odontologists are to conduct dental investigations on victims, dental radiography and dental charting or entering findings onto

the Post-Mortem sheets [29]. However, in a disaster zone, Forensic Odontologists may be apportioned several tasks that aid in the establishment of positive identity using dental evidence. The post mortem work may either be carried out at the recovery site set up at or near the disaster zone or at the autopsy room [26] but either way the investigation is carried on in a laboratory setting majorly governed by the nature of the disaster [29]. Forensic odontologists may start-off with basic procedures like collecting, identifying and describing dentition at the recovery site [31]. For example, details such as intact or fragmented jaw, condition of teeth in those jaws and dentures if any may be recorded. Information on damages such as fractures and damages either caused from burns may be identified and recorded. In cases of extreme damage such as when the jaws are severely damaged due to fire or when teeth are mobile, forensic odontologists take photographs and dental radiographs on site [31]. Loss of teeth during transportation and handling may usually be seen in children with mixed dentition, victims with severe periodontal diseases or even badly decomposed bodies. Therefore, care must be taken by forensic odontologists to make sure that all evidence collected must be secured with the head. The expected outcome of a successful victim identification process after a mass disaster is the correct identifications of victims. This can be achieved by following systematic process and maintaining quality management along the process [24].

American Board of Forensic Odontology guidelines

The American Board of Forensic Odontology (ABFO) was founded in 1976 to identify and certify dental experts involved in Forensic Odontology. The initial purpose of the Board was to certify practitioners, however, it has also expanded into constituting guidelines in the various areas of forensic odontology. One such area is ensuring appropriate systematic documentation of dental details. To achieve that, the ABFO has instituted guidelines for forensic odontologists. These guidelines are seen as the "gold standard approach" for forensic dentists across the globe [32]. In short they specifically bring the forensic odontologist to four alternative conclusions based on the evidence at hand. These conclusions are outlined in Table 3.

Table 3: Conclusions of the ABFO guidelines on identification criterion

ABFO conclusion	Explanation
Positive identification	This may be given when the ante mortem and post mortem findings match in sufficient details, without any unexplainable discrepancy, to give the impression that they are from the same individual.
Possible identification	Here ante mortem findings may be consistent with post mortem findings, but a positive identification with certainty may not be established owing to the poor quality of either the post mortem remains or ante mortem dental records.
Insufficient evidence	Information in the ante mortem and post mortem dental records are insufficient to draw a conclusion of any sort.
Exclusion	The findings in the ante mortem and post mortem dental records are clearly inconsistent with respect to many features [32].

Technological Advancements

Over the preceding couple of decades, there has been a steady growth and significant advancement in the technology and its applications in the field of forensic odontology. These advances have made the speed, specificity and sensitivity of the ability of odontology to contribute to disaster victim identification far more valuable than in the past. Some of these advances include.

Photographs: Charts, photographs [33, 34], plaster models and measurements and shape comparisons made from the traditional ruler and protractors [33] have been used in the past to manually compare dental features.

Study Models:
Study models have been advised and used in the past to preserve relative positioning of hard structures to preserve integrity of the evidence due to tissue breakdown [35].

CAT scanning: Use of CAD/CAM and CAT scan in the teeth and jaws has been widely documented and a range of unique features of an individual can be measured and matched to the CAT data. This has enhanced the ability to collected informative dental data far beyond the original planar films [36].

Bar coding:
Incorporation of bar codes into dentures and other prosthesis have been used in the past. These barcodes can hold large amounts of information about the person. The drawback of this technique was that the thickness of the acrylic resin made it hard to scan the actual barcode [37].

RFID tags:
Radio Frequency IDentification (RFID) tags are wireless communication devices that have been used to identify a person animal or an object when tagged. The most common method of using an RFID tag is to store a serial number and other information on a microchip that is inserted into the denture to identify a person. The chip transmits the information lodged in it through an antenna to a reader that converts the digital information using relevant soft-wares into information that can be interpreted [38].

3D scanning: The use of a 3D laser scanner to document evidence at the scene of crimes (and disasters) is now widely accepted [39]. They have been successful even to the level of tooth marks on chocolate. There has also been a mention about use of this method to obtain impressions of tools or teeth left on objects or people [39]. Examination and identification of bitemarks in foods using 3D scanning and comparison methods have been developed recently (Silvio et al 2011) [40]. Using 3D scanners, they examined time dependant changes related to identification of perpetrators based on their bitemarks in different foods like buttered bread, apple, cheese and a bar of chocolate and was found that it was possible to identify people based on imprints of teeth left on various foods even after 7 months. 3D scanning instruments like the Lava chair-side intra-oral scanner (COS) have been put to use for the purpose of obtaining digital impressions of dentitions in a clinical setting [41]. These high resolution, highly accurate intra-oral 3D "maps" are providing a new level of detail unheard of in dentistry previously. Some of the commercially available 3D scanners are available.

3D printing: Highly accurate re-creations of dental images/data can now be manufactured using 3D printing [42] for the last few years and it would be well worth to test if missing fragments of jaws found at disaster zones could be completed using a 3D scanner. If

need arises then these jaws could be printed using validated 3D printers. These technologies (and many more currently evolving) are being put to use in disaster victim identification, then collection and interpretation of data will be easier, quicker, more accurate and safer.

Discussion

This review exemplifies the role of dental identification and its importance in disaster victim identification. Dental identification is a simple yet effective method of identifying people in situations such as a mass disaster [12]. It is based on studying Ante-Mortem and Post-Mortem records to identify matching features. It is however essential to obtain all relevant ante mortem dental records, (e.g. dental casts, radiographs, photographs, dentures etc) to achieve a successful analysis [23]. Emphasis must also be placed on collecting quality post-mortem evidence. Advances in technology and adapting new techniques in the identification procedures will facilitate a more organized and systematic data collection. Dental identification is one of the quickest, cheapest and straight forward methods of identification available and its success is coherent with findings from other methods [20] .

Identification of people is crucial in any case involving victim identification. There may be cases where identification may be made harder by processes like advanced decomposition or unavailability of any other common means of identification such as identity cards, bank cards or membership cards. Dental identification plays a vital role in such cases [10]. As Antony J Hill et al have outlined, "Forensic odontologists are involved in all phases of disaster victim identification (DVI). The failure of DVI management to embed odontology teams within all phases of the investigation and to include them in management decisions throughout the operation may lead to delays in the reconciliation process and could possibly compromise the integrity of the DVI investigation [43]. The primary aim of any case of victim identification, whether in a disaster or not, must be to try and get the disaster zone to normalcy as early as possible as this may enhance the mental state of the local community. Finances and resources must be directed towards re-establishment of the disaster zone and aid the disaster victims that may directly or indirectly be involved in the

disaster and this is only possible when an efficient team works with full knowledge, adapting to a situation, makes use of advanced technologies and comes out with the best possible results.

Conclusion

This review emphasizes the need of advanced techniques in forensic odontology that may reduce working time and number of investigators required in the actual disaster zone such that finances and energy required in achieving a safe environment for the investigators to work could successively be deviated towards reinstating the disaster zone itself. In more than a few occasions, forensic odontologists from more than one country may be involved in the disaster victim identification process [23]. This may be good to exchange ideas information but it must be kept in mind that it is also an added expense. If we could use emerging technologies like 3D imaging and scanning at the disaster zone itself, that data could then be transferred to remote locations where a detailed analysis could be undertaken. This means lesser investigating personnel are required for the task. In future, regional dentists may be trained on using these 3D scanners that transmit all dental data to a remotely located central server, such that an investigating team may get into analysis quicker than what it takes with conventional methods. These scanners may also be used to store evidence that may otherwise deteriorate over time, or just as a backup, hence enabling a systematic approach to the process.

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