# DNA analysis in identifying mass disaster victims

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## Abstract
Disaster victim identification is very important for legal, administration, and humanity reasons. Disasters include airplane crashes, fire disasters, volcanoes, hurricane, tornadoes, wars and flood. Methods of identification include visual identification, fingerprints, DNA analysis, personal objects and odontology. DNA analysis is an important method of disaster victim identification particularly when other methods of identification are not possible or not conclusive. The current article enumerates and reviews the role played by DNA analysis in identifying mass disaster victims.

**Keywords:** DNA, Mass disaster, Forensic, Identification.

## Introduction
In recent years the world has experienced several mass disasters such as bombings, terrorism, hurricanes, earthquakes, air crashes. World health organization (WHO) defines disaster as "a sudden ecological phenomenon of sufficient magnitude to require external assistance". A disaster is an unexpected event that results in death of several people.[1] Natural disasters includes floods, natural fires, avalanches, earthquakes, tornadoes, volcanic eruptions, droughts. Man-made disasters include transportation disasters (e.g. road traffic accidents, rail, air and maritime transport disasters), construction disasters, fires and wars. Open disasters are disasters where victim's names are unknown. Examples are earthquakes and tsunami. In closed disasters, victim's names can be obtained. Examples are air crashes and hotel fires. Sometimes a combination of open and closed disaster can occur. For example- aircraft crash in public area.[1]

Traditional means of disaster victim identification include physical identification of documents, jewelry, and other belongings. More trustable methods include examination of dental data, hairs, and fingerprints. In 1985, Jeffrey's published the first paper on identifying individuals based on DNA analysis through mini satellite hybridization.[2]

According to Merriam-Webster dictionary, identification is defined as "the act of finding out who someone is or what something is".[3] Method of identification of victim is chosen depending upon several factors- the degree to which the human remains are damaged, the time for which body remained exposed, the condition of the remains and individual circumstances/situations. Methods used for identification of victims should be sound, reliable, practical and capable of being implemented in field conditions within a reasonable amount of stipulated time.

Primary and reliable means of identification include comparative dental analysis, friction ridge analysis, unique serial numbers from medical implants and DNA analysis. Secondary means of identification are meant to support identification by other means and are not meant to be used as sole method of identification, although there may be exceptions depending upon individual cases/circumstances/ situations. They include tattoos, medical findings, scars, sex, documents, unique personal effect, personal description; and clothing and property found on the body. Combinational identification method uses secondary identification methods in addition to available strong primary identifiers. Identification process should be accurate, impartial, and scientifically reliable and must withstand judicial and legal scrutiny.[1] Identification can be done based on circumstantial and physical evidences. Circumstantial evidences include personal effects such as clothing, pocket contents and jewelry. They should not be used as sole proof for identity. Physical evidence is obtained by internal and external examination of the remains and is a reliable source for identification. External examination can reveal presence of tattoos, scars and fingerprints which are highly useful for positive identification of the victim. Internal examination may reveal exclusive features of an individual such as previous surgical procedures, natural diseases, prosthesis, and previous trauma.[4]

### Importance of Identification
Identification provides closure to the living family members and friends of the victim, relieves them from uncertainty and facilitates grieving process.[5] Victim identification is important considering humanitarian, legal and administrative aspects. It is required to inform the legal next of kin, resolve property issues, for criminal/civil litigation, to identify victim-perpetrators, and for issuing of death certificates.[6]

**Disadvantages of visual method of identification**

A visual method of identification is not reliable as in case of large-scale disasters were the victims may be disfigured.[1] Visual method is subjective, is affected by cognitive anomalies and memory loss. Also, the visual method of victim identification is less reliable because of subjective factors and the stressful situation in which a relative or friend finds himself.[7] Interpol guidelines mention that victims should never be identified based solely on visual recognition method.[1]

**Importance of DNA analysis in identification**

Fragments of victims can only be identified through DNA analysis. DNA analysis is considered as one of the main modes of victim identification in mass disasters.[8] DNA identification was an integral part of DVI response in South East Asian tsunami incident.[9] DNA profiling can be carried out on a variety of body fluid and tissue types. It has the high statistical discriminative power of identifying one individual in quadrillions. DNA-based identification can be successful even if the body is significantly decomposed, partially incinerated, and irrespective of post-mortem interval and environmental conditions.[10]

Challenges faced in DNA profiling include the huge numbers of body and body fragments to recognize, the non-availability of family and direct reference samples due to the death of entire family and due to the extensive destruction caused by the disaster, the rate and speed of body recovery that may affect the quality of DNA extracted, and the extensive requirement of sophisticated equipment, software, and qualified personnel. DNA-based identification method in mass disasters necessitates multi-laboratory facilities.[11] Efforts are going on to reduce the time required for DNA analysis. Also, the government operated DNA databases were predicted to grow from approximately 30 million profiles in 2011 to 100 million profiles in 2015.[12] At present, it is prudent and practical to use DNA analysis based identification in conjunction with other modalities of identification such as forensic anthropology, odontology, radiology, and fingerprints. Interpol recommends the use of DNA-based identification in mass disaster in collaboration with odontology and dactyloscopy.[9]

DNA analysis was first used to identify mass disaster victims during Scandinavian Star ferry in 1990. Restriction fragment length polymorphism (RFLP) and a variable number of tandem repeats polymorphisms were used to identify the disaster victims. DNA-based identification also played a crucial role in victim identification in the Spitsbergen aircraft disaster in 1996, World Trade Centre attacks of 2001 and in South East Asian Tsunami disaster.[9]

DNA analysis plays a crucial role in the identification of victims in a mass disaster scenario. The present article enumerates and reviews the role played by DNA analysis in identifying mass disaster victims.

## Material and Methods

A search for English-language articles published between the 1st January 2001 to 31st December 2016 using the keywords DNA AND Mass disaster; DNA AND Mass disaster AND Forensic; DNA AND Mass disaster AND Identification, was made in the PUBMED database. The search yielded 342 articles. All the 342 articles were scrutinized by first reading the title and abstract of the article for suitability. 32 articles that contributed to the main aims of the project were selected among them. Five more articles were obtained by hand search. Totally, 37 articles were then reviewed.

**DNA analysis in Mass disasters**

Main goals of DNA typing in mass disasters are to identify victims, their associated body parts, and to identify criminals.[13] Samples that can be collected for DNA analysis include blood samples, blood stains, bone specimens and tissue specimens.[8] Multiple samples of different type may be required in few cases.[8] When obtained sample is insufficient or degraded, analysis of mitochondrial DNA is useful in identification of the victim.[13]

Severely charred bodies should be considered unsuitable for DNA analysis.[8] Victim identification by DNA includes collecting appropriate antemortem and post-mortem samples, matching and statistical weighting of the genetic match.[9] Antemortem samples include buccal swabs, Guthrie cards, and pathology specimens.[8] Antemortem samples should be obtained from more than one first-degree relative. It can also be obtained from the personal objects used by the deceased.

Proper labeling, documentation, and proper chain of custody are crucial for collecting the samples. Samples for DNA analysis should be kept cool. Otherwise, DNA preservatives such as genofix, sample matrix, regular salt, 95% (alcohol or white rum can be used). Post-mortem DNA samples from bone are best obtained from femur and metatarsal bone. In the case of teeth- molar teeth is preferable. If the body is less degraded, muscle tissue can be used.[9]

Precautions while collecting and handling samples for DNA analysis: - Utmost care should be taken that samples are not contaminated. Contamination can occur from someone handling the sample, contaminated instruments or from commingled remains. The sampling area should be clean and protective clothing should be used while handling the samples. Samples should be stored under appropriate conditions in appropriate containers. Clean disposable instruments should be used.[9] All samples should be labeled, individually wrapped in packing material with a chain of custody details.

Obafunwa et al. 2015, in their paper discussed the methods used for identification in DANA air crash incident. In DANA air crash incident, 148 out of 152 (97.4%) disaster victims were identified using combination of forensic odontology with DNA method.[14] Dental photographs and radiographs were taken first. Forensic odontology procedures included comparing antemortem and post-mortem dental records. Post-mortem dental charting, recording of fractures of mandible and maxillae, recording the presence of crowns, restorations, and prosthesis were also done by the dental team.[14]

Alonso et al. 2005, in their study described challenges of DNA profiling in mass disaster investigations. In the Yakolev-42 aircraft accident in Trabzon, Turkey of May 26, 2003, 62 out of total 74 total victims were Spanish military personnel. There were 85 remains. 30 out of 62 bodies were unidentified, whereas 32 were positively identified by the Turkish forensic team. All bodies were given by the Turkish authorities to the Spanish military commission for identification and repatriation of the remains. Bodies and remains were given to families in Spain without further investigation on identification. One year later, comparative DNA analysis among post-mortem body samples taken by the Turkish authorities and reference samples from victim's relatives proved that the 30 unidentified cases were miss-identified and consequently each family received a wrong body. A new DNA analysis from the exhumed bodies carried out confirmed all errors and offered concordance with the results obtained by the Istanbul Forensic Science Council from Post-mortem body samples.[5]

Alonso et al. 2005, in their article also mentioned about the DNA analysis done in Madrid terrorist attack. In the Madrid terrorist attack of March 11, 2004, 191 individuals were dead. 220 remains were analysed by DNA analysis. Also, mitochondrial DNA analysis was performed in one case. Combined DNA index system (CODIS) database was used to compare 220 body remains against 98 reference samples, including 67 samples from relatives, representing 40 family groups and 27 antemortem direct references.[5] DNA analysis resulted in 100% identification of victims.

Akhteruzzaman et al. 2015, in their article reported disaster victim identification by DNA analysis in Tazreen fashions garment fire incident. In Tazreen fashions garment fire incident in Bangladesh, 112 individuals were killed. 50% were initially identified by visual recognition and other methods which did not followed any Interpol protocol for DVI. Samples were collected from tissues (n=35), bone (n=2), teeth (n=22). Out of 59 unidentified dead bodies, 43 were confirmed by DNA analysis with the help of 68 biological relatives originating from 61 families.[15]

Ballera et al. 2015, in their article mentioned about how the dead were identified in Typhoon Haiyan. In Typhoon Haiyan that occurred in Tacloban city, out of 128 bodies, forensic experts identified that 66% were adults, 20% were children, 8% were adolescents and 5% were infants. Fourteen bodies were identified with the help of personal belongings that were present in the body bags. One body was identified by a family member. However, it should be noted that no bodies were recognized through clothing or through the photos of the dead persons. Visual recognition is helpful over DNA testing in situations where there is need for rapid identification or where there is no availability of DNA database of citizens. However, the authors suggested that DNA testing should be added in situations where there is availability of sophisticated DNA laboratories and when there is a need to identify small amounts of dead bodies.[16]

Herald et al. 2013, identified four victims of Boeing 737-800 air crash disaster that occurred in Mangalore on 22 May 2010. The first victim was identified through ornaments and clothes. Also, the victim's age was identified as between 12-16 years. Second victim was identified through cloth present on the unburnt region which had unique design, gold ornaments in nose and ear, and wrist watch. The identification was then confirmed by her relatives. Third victim was identified through numbers present in the partially burnt visiting card and also by gold ring in his finger. The gender was identified by the reminiscent of external genitalia. The soot-stained facial features of the victim were made clear by wiping with wet cloth with application of firm pressure. The fourth victim was identified through a piece of unburnt T-shirt and banian, and burnt wrist watch. The authors suggested that age, gender, stature, personal belongings are very helpful in identification of disaster victims. The authors opinioned that DNA identification method was not feasible in locations where there are few laboratories that perform DNA typing.[17]

The advantage of DNA typing is that samples can be obtained even from decomposed body parts such as bone. Schou et al. 2012, in their paper mentioned the methods used to identify victims in Thai tsunami. In Thai tsunami 2004 incident, the Danish DVI investigators were able to identify 70.3% of the victims by forensic odontology alone. 5.4% victims (2 cases) were identified through combination of fingerprinting and forensic odontology. 21.6% victims (8 cases) were identified through fingerprinting. Only one case was identified through DNA typing combined with fingerprinting. DNA typing was less used because of low quality of samples. It is to be noted that fingerprinting is unique and chances of identical fingerprints in two different individuals is estimated to be 1:64,000,000,000. Also, even identical twins do not have similar fingerprints. In this disaster identification process, DNA typing results arrived too late when compared to fingerprinting and dental identification.[18]

Lin et al, 2011 mentioned in their article about the strategies used to identify victims in Typhoon Morakot.

In Typhoon Morakot disaster in Taiwan, identification of victims was assisted by DNA typing and a search for rare allele. Y-STR loci and/or mitochondrial DNA (mtDNA) combination was used in identification, wherever it seemed appropriate. Out of 146 samples from 130 victims, 124 individuals were identified from a pool of 588 relatives. The victim samples were obtained from buccal swabs, blood samples, and bone fragments of phalanges, ribs, and clavicle. Also, the samples in the form of buccal swabs or blood samples were collected from their supposed relatives. Rest six victims could not be identified as they could not be related to any of their living relatives. Out of the 42 fingerprints obtained from 146 victims, only seven matched with the national database, which was confirmed by DNA typing. One victim was identified based on the presence of characteristic tattoo and bald head. Seven victims were identified as grandparents or grandchildren based on their probable age.[19]

Skinner et al. 2010, in their article mentioned that in between 1991-1999, in Yugoslavia conflict, out of 30000 missing individuals, two-third of the 15000 victims were identified through DNA. 23% of 3919 remains were identified through dental information.[20]

DNA fingerprinting is helpful in conjunction with dental records and fingerprints. In Indian Ocean tsunami, which occurred on December 26, 2004, more than 200,000 peoples were dead. Attempts were made to extract DNA from teeth pulp by crushing or sectioning the teeth. The DNA extracted was compared to antemortem DNA samples obtained from stored blood, material from toothbrush, shaving brush, hair clips, hair bands, lipsticks, bolster, combs or hair brush, parent or sibling DNA. In direct DNA matching, it is of utmost importance to ascertain the authenticity of the antemortem DNA records.[21] Bloodhound© is reported to conclusively identify all the 229 passengers and reconcile the 1277 samples of human remains collected from the crash site with the 250 personal effects and 310 reference blood/buccal samples collected from family relatives of the victims of Swissair Flight 111 crash on 2 September 1998.[21]

Bus and Allen., in 2014, in their article regarding Waco mass disaster, explained that out of 40 bodies which were impossible to identify by conventional methods, 26 bodies could be identified by DNA analysis. Bus and Allen stressed the importance of proper sampling techniques, storage, and protection against contamination and extraction methods with respect to DNA analysis. Faulty methods can lead to irreversible loss of data and errors in DNA analysis.[22]

Milos et al. 2007, in their article mentioned that 25,361 bone and tooth samples from Yugoslavia mass grave victims were successfully identified by DNA analysis even though they were buried for period ranging from 4-11 years. In this disaster, DNA was observed to be best preserved in femora and teeth, followed by tibiae, fibulae, humeri, crania, radii, and ulnae.[23]

Mundorff et al. 2009, in their study involving world trade center victims, observed that DNA sampling from lower limb elements without fibula yields higher success rates of identification by DNA typing. High DNA identification rate was also observed for patella. The authors attributed this to the increased density of patella bones. Also, skeletal elements covered by soft tissues yielded higher success rates in DNA typing than isolated bone fragments. Metatarsal and patella bones yielded 86% and 80.8% success rates. Tibia, femur and rib yielded 77%, 71%, and 71% success rates respectively. The authors recommended that DNA should be sampled from patellae, metatarsals, and foot phalanges of relatively intact bodies in mass disasters, since they not only yield higher success rates, but also they are easy to sample using a disposable scalpel rather than a bone saw, and are impermeable to contamination.[24]

Canturk et al. 2014, in their paper described the role of single nucleotide polymorphisms in forensic practices. Single nucleotide polymorphisms (SNP) are useful when DNA samples are degraded and when there is a kinship issue. Every individual has millions of SNPs. In mass disasters, when DNA fragments in the degraded samples are smaller than 200 bp with quantities lesser than 250pg, SNPs prove to be successful in human identification. Also, they are useful in determining ethnicity of an individual. SNPs have considerably lower mutation rates than STRs and hence are valuable in resolving kinship issues between genetically related real and alleged relatives in case of mass disasters.[25]

Biesecker et al. 2005, discussed the role of DNA identifications after 9/11 World Trade Centre attack. In the world trade center attack, there was a huge task for identification of almost 3000 victims. The victim remains ranged from a few nearly complete bodies to tiny fragments of charred bones. There was extensive fragmentation of remains with commingling and mixing with building materials. There were about 20,120 victim fragments. Till 2005, about 850 of the 1594 victim identifications for the 2749 victims were solely based on DNA analysis.[26]

Manhart et al. 2012, in their study identified all the 8 victims of the "Autobahn A19" disaster. Among the 8 victims, 7 victims were identified by DNA analysis. The remaining one case was identified by conventional method due to the presence of hip implant.[27]

In 2009 Victorian bushfires disaster, Hartman et al. 2011, discuss the DNA based victim identification through kinship or direct matching of DNA profiles. 82% of the DNA identifications were made through kinship matching of familial reference samples to that of victim post-mortem samples. Out of 173 deceased, identification of 67 bodies was aided by DNA analysis. 55 were identified based on kinship matching. Most of

the cases were identified by dental means before the DNA analysis results could arrive.[28]

Calacal et al. 2005, identified the exhumed skeletal remains of fire tragedy child victims in Manila, December 1998, using conventional identification methods reinforced by autosomal/Y-chromosomal STR haplotyping. Though the skeletal remains were subjected to burning, burial and exhumation, the authors were able to identify 18 out of 21 remains by this technique. Conventional method of identification included radiologic, pathologic, anthropological, and dental examinations. Three female victims could not be identified because of lack of appropriate antemortem data to match with the post-mortem data. Two victims were readily identified due to the availability of antemortem umbilical tissues. Rest cases were identified by using reference blood samples from parents and relatives. In fire disasters, the victim remains are charred and heat causes DNA degradation. Vertebrae were collected from intact spinal columns of the victims for DNA analysis. Nine autosomal STR markers HUMCSF1PO, HUMFGA, HUMTPOX, HUMTH01, HUMFES/FPS, HUMVWA, HUMF13A01, HUMDHFRP2, and D8S306 plus amelogenin (HUMAMEL) were used for DNA analysis. 16 male samples identified using human amelogenin and reference paternal samples were subjected to Y chromosome-specific DNA typing using eight Y-chromosomal STR markers -DYS19, DYS389I, DYS389II, DYS390, DYS391, DYS392, DYS393, and DYS385. Age was estimated by gross examination of bones and analyzing dental development. Complete STR profiles with 9 autosomal markers were generated in 15 out of 21 bone samples. Sex identification was successful in all bone samples using amelogenin marker.[29]

Barberia et al. 2015, in their article mentioned about the victim identification methods performed in Castelldefels railway accident. In Castelldefels railway accident, Barcelona June 23, 2010, 12 peoples were dead. Samples in the form of muscle and blood were taken from each dead body and body fragments for genetic identification. There were 12 torsos, 1 lower body and 138 remains. Fingerprints, photographs, personal belongings were collected from missing persons homes to assist in identification. Most of the victims were quickly identified by comparing their fingerprints with those of civilian database. All the victims except one were identified by means of fingerprinting and DNA analysis. Autosomal STRs and Y-chromosome markers was used in DNA analysis.[30]

Campobasso et al. 2003, in their article mentioned about how the victims were identified in Italy's deadliest building collapse. In 1999, due to collapse of apartment in Foggia, Italy, 61 people died. The bodies of majority of the victims were well preserved and were identified visually or by comparing body features such as scars, dental or orthopedic prostheses, previous surgery, and clothing or personal effects after obtaining information from the victim's relatives and friends. Among the two bodies which were burnt, one was identified by dental comparison and another by DNA analysis.[31]

Meyer. 2003, mentioned in his article about the role of DNA based victim identification method in Kaprun cable car fire disaster. In Kaprun cable car fire disaster which occurred on November 11, 2000; 155 people were dead. Morphological identification was not possible because of the severe burning of bodies. However, all the remains were identified successfully through DNA analysis within 19 days after the incident. The disaster was unique in that the lists of passengers in the cars involved were not known. Post-mortem samples for DNA analysis were collected from cardiac blood and blood remnants, skeletal muscle tissue, urinary, and gall bladder swabs. First preference was for cardiac blood and swabs from the urinary bladder. If these were not available, then samples were collected from skeletal tissues. Reference samples were collected from toothbrushes, shavers, clothes, hair brushes, towels, used dishes, buccal swabs of close relatives and food leftovers with bite marks. Victim blood samples and applicable comparative material matched typed for DNA showed positive matching resulting in 100% identification rate. Most of the victims were young and healthy and did not have dental treatment and hence there was the absence of dental records. DNA analysis for identification of victims was preferred in this disaster because the investigators had experience of previously successfully identifying all 11 severely burnt and cooked remnants of the 1999 Tauern tunnel fire disaster by using this same modality. Sex was determined by examination of remnants of external genitalia in all cases.[32]

Morgan et al. 2006, in their paper described about the disaster victim identification that were performed following the South Asian tsunami disaster. In tsunami disaster that occurred on 26 December 2004, in Thailand, Indonesia, and Sri Lanka, most of the victims were identified using dental and fingerprinting data and few were identified by DNA analysis. In Indonesia, around 500 victims were identified using identity cards, jewelry, and mobile SIM cards. In Sri Lanka, DNA and dental records were used to identify 155 bodies. In Thailand, during the initial phase, without the help of forensic specialists, the local police and physicians identified around 1600 bodies by external examination, photography, and recording of all personal effects and by using DNA collected from hair, soft tissues, ribs, and teeth. Till seven months after the disaster, the Thai victim identification Centre identified 2010 victims, with 1800 bodies still left unidentified. 61% (n=1,235) of victims were identified by dental examinations, 19% (n=378) by fingerprint records, 1.3% (n=26), 0.3% (n=6) were identified using physical evidence, and 18% (n=365) were identified through more than one method.

The authors recommended that visual recognition or photographs of fresh bodies constitutes the simplest non-forensic identification of victims and should be facilitated in all natural disasters. If adequate resources are available, this method can be supplemented by forensic methods such as dental, fingerprint and DNA analysis. However it is cautioned that body injuries, or the presence of blood, fluids, or dirt, especially around the head, will reduce the accuracy of visual identification method. DNA identification was not an important method of identification in Thailand since it was expensive, technically demanding, and logistically problematic to carry out on a large scale. The authors recommended that DNA identification method should not be a first-line method for identification, instead should be undertaken only when physical, dental and fingerprint methods prove unsuccessful.[33]

Complex DNA mixtures when analyzed with standard STRs have low evidential value. Voskoboinik. et al, 2015, examined the role of commercially available HumanCytoSNP-12 microarrays in identifying disaster victims from complex DNA mixtures. They observed that a set of 3000 SNPs specifically selected for this purpose can accurately identify the victim from complex DNA mixtures of various compositions. This method has high sensitivity in that it can identify an individual even if he contributes 5% to the DNA mixture of at least 5ng.[34]

Weedn and Baum, 2011, suggested that in mass fatality accidents, DNA specimens should be collected from all human remains, even if they may not be used for DNA analysis. Initial quick identification should be made by other methods. Direct reference specimens for DNA includes eyeglasses, hearing aids, wrist watches, mouthpieces of musical instruments, chewing gums, cigarette buts and pipes. Half of the nuclear DNA in chromosome is inherited from mother and another half from father. mtDNA is inherited from mothers to their male and female children. Y chromosomes are found only in males and are inherited from fathers. In case of extensively fragmented remains post-mortem samples should be taken from red muscle (~10 g). Ribs are preferred for moderately decomposed remains and long bones are preferred for older remains. In case of charred body, samples from scraping of urinary bladder mucosa are preferable. In case of severely decomposed and skeletonized remains, femur and tooth roots are preferred for sampling. In case of fresh body, blood and buccal swabs can be used for DNA analysis. It is wise to obtain two specimens from two types of tissues. Examples are: blood + oral swabs or blood + red muscle, red muscle + rib end. Blood is dried on FTA cards for safe storage.[10]

Holland et al. 2003, in their paper mentioned about the Bode technology group, USA, which developed a quality, high throughput DNA analysis procedure for skeletal samples for identification of world trade center attack victims. They analyzed 12849 skeletal samples and obtained a success rate of 65.7%. They suggested that BodePlex mini-STR systems are robust, sensitive, and effective and has success rates tripled when compared to Profiler Plus and CO filer systems. It reduces the amplicon size of the STR loci and enhances the amplification parameters.[35]

Nandineni et al. 2010, in their article highlighted the important role DNA analysis played in the identification of Air India Express flight IX812 crash disaster that occurred on 22 May 2010. The air crash resulted in death of 158 victims. 136 victims were identified based on their morphological characteristics and/or personal effects. DNA analyses for victim identification were carried out in remaining 22 victims and were compared with 32 relatives who claimed the body. Except one victim in which DNA was obtained from tooth, DNA from rest of the victims was obtained from muscle tissue/liver. DNA was extracted from blood samples of relatives. DNA analysis assisted in identification of 10 bodies. DNA analysis also proved that other 12 victims were not the relatives of any of the 32 claimants. This meant that at least 12 families got bodies that actually did not belonged to their relative. This shows that identification through morphological features and personal features can be misleading and erroneous. DNA analysis can help the forensic personnel to positively identify the victims or exclude the victim from being possible relative of claimants.[36] However, in this disaster it was difficult to identify and distinguish between the bodies of two closely related male victims i.e. between a father and brother or between two brothers through DNA matching alone, where the claimant of the body was also male.[37]

Alonso et al. 2005, in their paper highlighted challenges of DNA analysis in mass disaster investigations. Mass disasters necessitate managing, analyzing, and comparing large numbers of biological samples and DNA profiles. Also, it requires software with bioinformatics and statistical tools for searching DNA database and likelihood ratio calculations. 13-17 nuclear STR markers should be analyzed from family reference samples such as- (a) either or both biological parents of the victim, (b) biological mate of the missing person and their child/children, and (c) multiple biological full siblings (sharing the same parent as the victim). Buccal swabs and blood are recommended samples for both nuclear and mitochondrial DNA analysis.[5]

Recent advances that aid DNA analysis include technologies that aid in genetic identification such as mRNA analysis, microarray techniques, oligonucleotide microarrays, next generation genome sequencing, microfluidic systems, nanotechnology; Fluorescence in situ hybridization (FISH) probes specific for X and Y chromosomes which can differentiate between male and female cells; transcriptome variations in individuals and populations.[2,13]

## Conclusion

DNA analysis is currently a gold standard for identifying mass disaster victims. DNA analysis is the main method of choice to identify individual mass disaster victims from severely fragmented and commingled bodies or severely charred, decomposed or skeletonized bodies. New technologies and commercial kits have made possible DNA analysis to be carried out in short duration of time. Also, modern technology has enabled to carry out DNA analysis even with very small amounts of available DNA. During DNA-based identification process, utmost care has to be taken to collect and preserve body tissues for later DNA extraction as fast as possible, since DNA begins to degrade since the time of death and this degradation can be accelerated by environmental factors such as humidity. The personnel collecting the body tissue for later DNA analysis should have thorough knowledge about from which tissue should be collected, depending upon the state of the tissue and environmental factors. Multi-rooted teeth, long bones such as that of the femur and red skeletal muscle represent the best source for DNA sampling. DNA reference samples should preferably be collected by duly obtaining the informed consent of the person except in cases of public welfare and public security needs. Care should be taken to immediately preserve the collected DNA samples with available preservation methods and the collected samples should be processed as soon as possible. Utmost care should be taken not to contaminate the DNA samples. Reference family samples should be preferably taken from victim parents, when this option is available. DNA analysis when combined with other methods of identification such as odontology and fingerprinting offers high success rates in identifying the victims. Visual recognition method is subjective and is prone to serious unintended errors. Hence DNA analysis method of identification method is reliable and far superior to the visual method of identification. With the advent of microfluidic systems, nanotechnology, and next-generation genome sequencing technology and with the ever increasing DNA databases of governments of various countries, it should be possible in the future to develop a point of care chip to rapidly conduct DNA analysis and matching. Hence DNA analysis should be considered and planned in every mass disaster incident. DNA analysis should be carried out on all the victim body and fragments regardless of the body being initially identified by other modes of identification. It can be safely concluded that DNA analysis has revolutionized and has significantly aided in the identification of mass-disaster victims, especially when used in conjunction with other common methods of identification such as dental methods and fingerprinting.

## References


1. INTERPOL. DVI guide. 2013. Available from Internet: https://www.interpol.int/INTERPOL-expertise/Forensics/DVI-Pages/DVI-guide. Accessed 02/01/2017.
2. Ziętkiewicz E, Witt M, Daca P, Zebracka-Gala J, Goniewicz M, Jarząb B, et al. Current genetic methodologies in the identification of disaster victims and in forensic analysis. *J Appl Genet* 2012;53(1):41-60.
3. Merriam-Webster. Identification. Available from Internet: https://www.merriam-webster.com/dictionary/identification. Accessed 02/01/2017.
4. Brough AL, Morgan B, Rutty GN. The basics of disaster victim identification. *J Forensic Radiol Imaging* 2015;3(1):29-37.
5. Alonso A, Martin P, Albarrán C, Garcia P, Fernandez de Simon L, Jesús Iturralde M, et al. Challenges of DNA profiling in mass disaster investigations. *Croat Med J* 2005;46(4):540-48.
6. Caenazzo L, Tozzo P, Rodriguez D. Ethical issues in DNA identification of human biological material from mass disasters. *Prehosp Disaster Med* 2013;28(4):393-96.
7. Nuzzolese E, Di Vella G. Future project concerning mass disaster management: a forensic odontology prospectus. *Int Dent J* 2007;57(4):261-66.
8. Hartman D, Drummer O, Eckhoff C, Scheffer JW, Stringer P. The contribution of DNA to the disaster victim identification (DVI) effort. *Forensic Sci Int* 2011;205(1-3):52-8.
9. Montelius K, Lindblom B. DNA analysis in Disaster Victim Identification. *Forensic Sci Med Pathol* 2012;8(2):140-47.
10. Weedn VW, Baum HJ. DNA identification in mass fatality incidents. *Am J Forensic Med Pathol* 2011;32(4):393-7.
11. Corach D. Mass disaster victim identification assisted by DNA typing. *Molecular Diagnosis* 2009 Aug 21:407-16.
12. Williams R, Wienroth M. Identity, mass fatality and forensic genetics. *New Genetics and Society* 2014;33(3):257-76.
13. Sakari SL, Jimson S, Masthan KM, Jacobina J. Role of DNA profiling in forensic odontology. *J Pharm Bioallied Sci* 2015;7(Suppl 1):S138–S141.
14. Obafunwa JO, Ogunbanjo VO, Ogunbanjo OB, Soyemi SS, Faduyile FA. Forensic odontological observations in the victims of DANA air crash. *Pan African Med J* 2015; 20:96.
15. Akhteruzzaman S, Hasan MM, Hossain T, Mazumder AK, Momtaz P. Disaster Victim Identification by DNA analysis: The Tazreen Fashions Garment Fire Incident Experience in Bangladesh. Biores Comm 2015;1(2):116-20.
16. Ballera JE, de los Reyes VC, Sucaldito MN, De Guzman A, Sy L Jr, Zapanta MJ, et al. Management of the dead in Tacloban City after Typhoon Haiyan. *Western Pac Surveill Response J* 2015;6 Suppl 1:44-7.
17. Herald D'Souza D, Vaswani VR, Badiadka KK. Identification of four differently injured victims of the Mangalore air crash disaster. *J Forensic Nurs* 2013;9(4):243-45.
18. Schou MP, Knudsen PJ. The Danish Disaster Victim Identification effort in the Thai tsunami: organisation and results. *Forensic Sci Med Pathol* 2012;8(2):125-30.
19. Lin CY, Huang TY, Shih HC, Yuan CH, Chen LJ, Tsai HS, et al. The strategies to DVI challenges in Typhoon Morakot. *Int J Legal Med* 2011;125(5):637-41.

20. Skinner M, Alempijevic D, Stanojevic A. In the absence of dental records, do we need forensic odontologists at mass grave sites? *Forensic Sci Int* 2010;201(1-3):22-6.
21. Lau G, Tan WF, Tan PH. After the Indian Ocean tsunami: Singapore's contribution to the international disaster victim identification effort in Thailand. *Ann Acad Med Singapore* 2005;34(5):341-51.
22. Buś MM, Allen M. Collecting and preserving biological samples from challenging environments for DNA analysis. *Biopreserv Biobank* 2014;12(1):17-22.
23. Milos A, Selmanovic A, Smajlovic L, Huel R, Katzmarzyk C, Rizvic A, et al. Success rates of nuclear short tandem repeat typing from different skeletal elements. *Croat Med J* 2007;48:486–93.
24. Mundorff AZ, Bartelink EJ, Mar-Cash E. DNA preservation in skeletal elements from the World Trade Center disaster: recommendations for mass fatality management. *J Forensic Sci* 2009;54(4):739-45.
25. Canturk KM, Emre R, Kınoglu K, Başpınar B, Sahin F, Ozen M. Current status of the use of single-nucleotide polymorphisms in forensic practices. *Genet Test Mol Biomarkers* 2014;18(7):455-60.
26. Biesecker LG, Bailey-Wilson JE, Ballantyne J, Baum H, Bieber FR, Brenner C, et al. Epidemiology. DNA identifications after the 9/11 World Trade Center attack. *Sci* 2005;310(5751):1122-3.
27. Manhart J, Bittorf A, Büttner A. Disaster victim identification-experiences of the "Autobahn A19" disaster. *Forensic Sci Med Pathol* 2012;8(2):118-24.
28. Hartman D, Benton L, Morenos L, Beyer J, Spiden M, Stock A. Examples of kinship analysis where Profiler Plus™ was not discriminatory enough for the identification of victims using DNA identification. *Forensic Sci Int* 2011;205(1-3):64-8.
29. Calacal GC, Delfin FC, Tan MM, Roewer L, Magtanong DL, Lara MC, et al. Identification of exhumed remains of fire tragedy victims using conventional methods and autosomal/Y-chromosomal short tandem repeat DNA profiling. *Am J Forensic Med Pathol* 2005;26(3):285–91.
30. Barberia E, Martin-Fumado C, Galtes I, Subirana-Domenech M, Puigbarraca-Sol L, Vidal-Gutierrez C, et al. Managing the identification of the mortal victims run over by a train in the Castelldefels railway accident (Barcelona). Leg Med (Tokyo).2015;17(5):366–70.
31. Campobasso CP, Falamingo R, Vinci F. Investigation of Italy's deadliest building collapse: forensic aspects of a mass disaster. *J Forensic Sci* 2003;48(3):635-39.
32. Meyer HJ. The Kaprun cable car fire disaster--aspects of forensic organisation following a mass fatality with 155 victims. *Forensic Sci Int* 2003;138(1-3):1-7.
33. Morgan OW, Sribanditmongkol P, Perera C, Sulasmi Y, Van Alphen D, Sondorp E. Mass fatality management following the South Asian tsunami disaster: case studies in Thailand, Indonesia, and Sri Lanka. *PLoS Med* 2006;3(6):e195.
34. Voskoboinik L, Ayers SB, LeFebvre AK, Darvasi A. SNP-microarrays can accurately identify the presence of an individual in complex forensic DNA mixtures. *Forensic Sci Int Genet* 2015;16:208-15.
35. Holland MM, Cave CA, Holland CA, Bille TW. Development of a quality, high throughput DNA analysis procedure for skeletal samples to assist with the identification of victims from the World Trade Center attacks. *Croat Med J* 2003;44(3):264-72.
36. Nandineni MR, Prasad SPR, Goud ChV, Negi DS, Nagaraju J, Gowrishankar J. DNA- based identification of victims of Mangalore air crash of May 2010. *Curr Sci* 2010;99(3):341-42.
37. Menezes RG, Shetty BS, Rastogi P, Padubidri JR, Babu YP, Nagesh KR, et al. The Mangalore aircrash of 22 May 2010: practical problems related to identification of the dead in a populous developing country. *Med Leg J* 2012;80(Pt 4):151-54.