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Review Article

Identification methods in mass disasters

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Abstract

Different numbers of people are affected in mass disasters. Identification of the disaster victims is a very important issue. For an accurate identification process, good and fast management of this process is of great importance. Identification of the victims includes investigating the disaster field, autopsy and following that post mortem data collection, ante-mortem data collection, and comparison of collected data. If these steps can be applied properly, identification of victims will be completed successfully. There are different techniques for victim identification in mass disasters and these methods can be divided into two categories as primary identification methods and secondary identification methods. Primary identification methods are more reliable than secondary identification methods. Fingerprint analysis, DNA analysis, medical records of the victims & physical examination and dental examination are primary identification methods. Visual identification and determination of personal belongings of the disaster victims are secondary identification methods. In the light of these methods, the identification process will be completed with an accurate evaluation.

Keywords: Disaster victim identification, fingerprint, DNA, dental examination

INTRODUCTION

Classification of disasters

A sudden event or events that cause significant damage or loss of life and disrupt the normal functioning of a community or society is called a disaster.

Disaster victim identification (DVI) is the process of identifying victims of a mass fatality incident, such as a natural disaster, accident or terrorist attack, after they have died. The aim of DVI is to determine the identity of each victim so that their families can be notified and their remains can be handled appropriately. This process involves various scientific techniques and methods, including forensic odontology, DNA analysis, fingerprinting, and anthropological analysis. Identification of victims following a mass death involves collecting and analyzing official, physical, and personal information for each deceased individual. It is essential to complete this identification process as quickly as possible to minimize the psychological impact on surviving families and expedite the recovery process. [1]. Regardless of the scale of the event, the primary goal of entities involved in DVI is to accurately identify victims using any viable means available. Although various countries have their own established standards and protocols for conducting DVI, in 1984, the International Criminal Police Organization (INTERPOL) published a comprehensive DVI guide to promote universal practices and ensure proper identification techniques are utilized [2].

Disasters can occur in many ways, either naturally, such as earthquakes, hurricanes, floods, forest fires, and volcanic eruptions,

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or man-made, such as terrorist attacks, industrial accidents, and transportation accidents [3].

We can classify disasters under two main headings;

●Natural disasters: Disasters caused by natural events such as earthquakes, hurricanes, floods, forest fires and tsunamis are included in this group.

●Technological disasters: Disasters caused by man-made technology and systems are included in this group. Examples of such disasters are industrial accidents, transportation accidents, nuclear accidents and explosions.

Disasters also can be classified into two groups known as "open disasters" and "closed disasters" based on the assumption that the event causes numerous specific and non-specific victims. In an open disaster we know the victims names but in closed disasters we don't. Earthquakes or tsunamis can be an example for open disasters. But a hotel fire or an airplane crash can be classified as a closed disaster [4].

They are also disasters that are caused by the combination of several factors like armed conflict or political instability. Such disasters are called complex emergencies [5].

There are several methods used for disaster victim identification (DVI), depending on the circumstances of the disaster and the available resources. Some common methods are visual identification, dental identification, fingerprint identification, DNA analysis, anthropological analysis, personal effects and belongings, medical records and implants [6,7].

In most cases, a combination of these methods is used for identification. Teeth, fingerprints and DNA are used as primary identifiers in DVI studies, as they remain intact for a long time and can be measured by scientific methods [8]. It's important to know that disaster victim identification can be a complex process, and it requires careful documentation, coordination, and communication among different agencies.

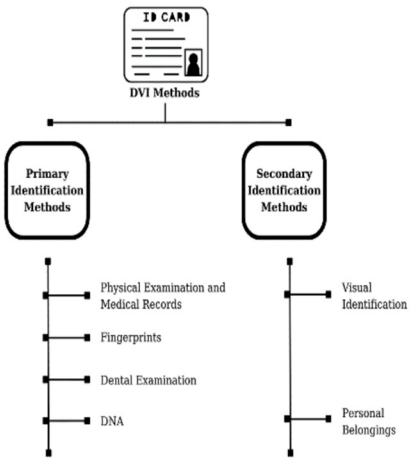

Figure 1. Summary of disaster victim identification (DVI) methods

Disaster Victim Identification Methods

Creation of proper guidelines for disaster victim identification is very important. According to information given by Interpol, the first guideline for DVI was produced in 1984 and updated every five years [9].

Primary Identification Methods

Physical Examination and Medical Records

The accurate identification of individuals involved in a mass fatality incident can be difficult, depending on the quality and availability of information about the victims [10]. Interpol has categorized this information into two types: circumstantial and physical evidence. Circumstantial evidence includes personal belongings such as clothing, watches, keys. However, it should never be relied upon alone to identify the individuals [11].

On the other hand, physical evidence obtained through external or internal examination of the individual. General external examination can reveal important data for identification, such as body anomalies, tattoos, scars, and wounds. Autopsy findings, such as pacemakers and prostheses, can also provide valuable information [12]. Similarly, internal examination can provide evidence of previous surgical procedures, natural disease, or prosthetics, which may be specific to the individual. Interpol has established standard operating procedures for gathering this physical information due to its significance in accurate identification.

Fingerprint Examination

Fingerprint examinations are one of the most reliable methods used for identification for many years. The structure consisting of raised linear lines on the fingertips and forming folds by coming together in different variations in each person is called the papilla line. Fingerprints are formed by the contamination of the biological fluid secreted by the body and accumulated on the papilla lines [13].

Fingerprints, which begin to form in the mother's womb and have personal shapes, have the characteristics of being dissimilar, unchanging and classifiable. There is no absolute overlap in the papilla lines in two people or in one person's fingers. Even identical twins have different fingerprints. This is due to the irregular formation of the skin on the palms of the hands and soles of the feet during the embryonic period. The uniqueness arises thanks to the large number of cracks and the different formation of papilla lines. Papilla lines form after the fourth week of the embryo and they remain present after death. They reappear at the same rate in injuries that occur on the surface. In this way, they are used as an identification method with high discrimination power.

The pattern of fingerprints corresponds to the unique arrangement of friction ridges. These friction ridges are classified into three primary types - loops, whorls, and arches - each characterized by

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distinct variations in their shape and the relationship between the ridges. As seen in Figure 2, the three basic fingerprint patterns are as follows: (a) the arch, which is the simplest of all configurations; (b) the loop, where ridges flow towards the margin of the digit - if the loop opens towards the ulnar margin, it is known as an ulnar loop, while if it opens towards the radial margin, it is a radial loop; and (c) the whorl, which is the most complex of the three patterns [14].

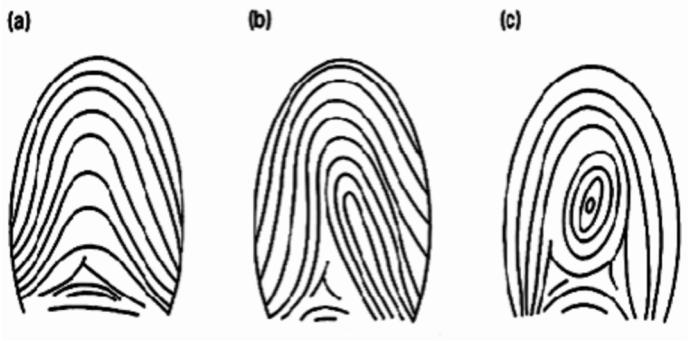

Figure 2. Major types of fingerprint patterns a) arch, b) loop, and c) whorl patterns [15]

Dental Examination

Dental identification is a crucial part of the disaster victim identification process. The vast array of dental characteristics available to us is an abundant source of information [16]. From the number of teeth present to their distinctive variations and history of dental procedures, each aspect provides unique insights into a person's identity. This method has been shown to be highly effective in cases where human remains are unidentifiable, such as when they are skeletal, decomposed, burned, or only partial.Identification with teeth is especially useful in situations where there has been a high number of casualties. If the features of the victim are recognizable, identification should be based on facial features or fingerprints. Estimating age in certain samples can be easier due to tooth development in children and adolescents or age-related morphological changes in adults. Dental age can be estimated through various methods, such as analyzing age-related morphological or radiological parameters. To ensure accurate recording of all dental characteristics, it is recommended to use both color photography and radiography.

For better access to the dentition, it is recommended to use non-destructive techniques. Jaws should not be removed by dental experts as a general rule, unless a more specific examination is necessary.

The 2004 Indian Ocean earthquake and tsunami was a major open disaster for the Thai government. The Japanese government initially classified the disaster as open too. However, after conducting over 3,000 inquiries and reviewing a significant amount of information, the Japanese government reclassified the event as a closed disaster due to their comprehensive knowledge of all Japanese citizens and nearly all Japanese victims in the disaster was accomplished through dental findings [17].

The data was divided into two categories: post-mortem (PM) data, collected during forensic medicine autopsies at the disaster site, and ante-mortem (AM) data, collected in the victim's native country. The dental information for each victim was entered into a computer system and compared to identify matches. If a match was established, it was reviewed and confirmed by forensic odontologists and Thai authorities, and an official death certificate was issued. The matching of the AM and PM files was a crucial step in verifying the identity of the victims [18].

Also estimating the dental age post-mortem allows forensic odontologists to narrow down their search for matching ante-mortem files within a specific age range among the potential candidates for identification from the missing persons list. Furthermore, lip prints (morphological differences in the wrinkles of the red lip) are also distinctive and employed in personal identification [19].

DNA Analysis

DNA is one of the best reliable identification methods. In mass disasters, diverse factors may be effective in the identification process. Intermixing of victim remains, decomposition or deterioration of body integrity are some of these factors and due to them, anthropological analysis and physical characteristics may not be sufficient for identification. Due to these factors, DNA profiling became the gold standard [20].

In identification processes, it is important that samples maintain their durability. Because in major disasters, identification can take a very long time and the time taken until the samples are analyzed may vary. To illustrate, in the World Trade Center attack, more than 2700 people lost their lives on September 11th 2001 [21].

With people from many different fields working together, approximately 1500 victims were identified through June 2003. Even though the process seems like two years, the majority of these identifications were performed within the 8-12 months after the attack [21]. According to this information, it can be said that it is important that the samples are kept in good condition.

In disaster victim identification, different parameters may affect DNA identification goals [22]. Number of victims involved in the disaster, places where bodies are found, extent and mechanism of body fragmentation are some of these factors. Degradation rate of DNA may be affected by many factors depending on the environment. Lastly, availability of DNA reference samples is important for identification of victims.

The shorter the time until the DNA analysis, the better the damage from external influences can be managed. In order to achieve that Rapid DNA Identification systems are developed. In a study, this system was evaluated in two different scenarios (human bodies stored in a morgue/cooler and placed above ground) that may be faced in disasters. In addition, Rapid DNA Identification system was assessed in different types of tissues. The research

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group concluded that all samples types from refrigerated remains showed excellent DNA identifications for 3-month period while in the other group; tooth and bone samples showed excellent DNA identifications for 1-year and buccal swabs showed excellent DNA identifications up to 11 days exposure [23].

It is very important to manage the situation well in mass disasters. Preserving the bodies of victims in good conditions is one of the most important steps in terms of the quality of the analyzes to be made. In a study in which the identification process of the victims of the tsunami in 2004 was handled in Thailand, Indonesia, and Sri Lanka, it is stated that rapid decomposition of bodies caused serious problems for the identification process after 24-48 hours. In addition, they stated that identification of victims was achieved by dental and fingerprint data in Thailand. Identification by DNA was applied for the few number of victims [24]. Depending on the type of disaster, body integrity may not be preserved in mass disasters. While 86.2% of the samples studied in the collapse of a mine tailing dam in Brazil were body parts, only 13.8% were bodies that had preserved their integrity. In the disaster that killed 270 victims, 603 biological materials were studied and 259 of these victims could be identified [25].

We have previously stated that different identification methods can be used depending on the type of disaster and the time of analysis. In this case, while the identification was made with fingerprints in the first weeks following the disaster, depending on decomposition of body parts, the DNA method was preferred [25].

In the context of disaster victim identification (DVI), short tandem repeats (STRs) are usually used in DNA testing. These biomarkers are found in 2-7 nucleotide base length and they are inherited in a proper way to classical Mendel characteristics [26]. For the DVI process; DNA is isolated and copied by PCR. Then, fragment analysis is done and STR comparison is conducted with reference samples. Usually, autosomal STRs are analyzed but in some cases gonosomal STRs (X-STR, Y-STR) may be investigated additionally.

Another type of biomarkers that may be useful in DVI applications are single nucleotide polymorphisms (SNPs). They are single base changes that occur in the DNA sequence. These changes are base changes, insertions, and deletions. SNPs can be used in forensic sciences to determine paternity and lineage, or to determine the phenotypic characteristics of an individual. SNPs that are not as polymorphic as STRs need to be included more in number in order to provide equivalent information with STRs on discrimination power [27]. In the concept of DVI, SNPs can be used as supportive biomarkers in some cases.

STR typing was conducted in the World Trade Center human identification project and the success rate of DNA profiling was 75% of the examined cases. Merging of soft tissue transfer and other remnants, there may be some problems. According to the project data, they concluded that if only a soft tissue test is applied, there may be problems in DNA testing. Therefore, it was stated that it is important for anthropologists to take part in studies and identify inconsistencies [28].

DNA degradation is one of the important issues in DNA testing. In mass disasters, DNA degradation may be observed at different rates depending on distinct conditions. In order to solve this problem mini primer sets are implemented for reducing STR size. Yudianto and Setiawan conducted a study that investigates mini primers for three different loci at two different temperatures. According to study; as temperature rises, DNA content decreases. Out of these three loci, only one of them was detected at highest temperature [29]. If the number of such loci can be tested for different parameters, they can become quite useful in DVI studies.

In disaster victim identification DNA testing is usually performed by using STRs. However, some cases may require additional biomarkers. To illustrate, a boat with more than 500 migrants sank near Lampedusa in 2013 and most of the identification was done by using 16 autosomal STRs. Yet, in some cases, gonosomal and lineage (Y-chromosome and mtDNA) markers were used as additional markers [30].

Depending on the place where the disaster occurred, degradation rate and quality of DNA may be affected. Unlike traditional methods like STR typing, other methods may be useful. Mitochondrial DNA (mtDNA) analysis is one of the methods that can be used in such cases.

Mitochondria have a unique division cycle and a circular DNA of 16,569 base pairs [31]. Mitochondrial DNA (mtDNA) analysis is one of the analyzes used in forensic sciences since 1996 [32], and hypervariable regions called HVRI and HVRII, which have a highly polymorphic structure in the non-coding D loop region of mtDNA, are analyzed [31].

MtDNA is passed on from mother to child. Therefore, all maternal line relatives share the same mtDNA. When there is a limited amount of biological samples, mtDNA is a very useful biomarker. Because mtDNA is found in greater numbers (with a high copy number) than other types of DNA. Individual identification capability of mtDNA is limited due to the lack of recombination, but it is an advantageous method for confirming maternal lineage and it may be used in disaster victim identification (DVI) triage [33].

In an evaluation made in 2021, It has been stated that the identification of the victims of the 2011 Great East Japan Earthquake is still ongoing. Victims are identified by mtDNA when identification is not available by using nuclear DNA. Identification by mtDNA is a useful technique but it is time-consuming, expensive and requires well-trained analysts [34].

In order to detect genetic relatedness between victims of disasters with relatives, different techniques may be used and Machine Learning (ML) algorithms are one of the novel techniques. In a study, ML was applied in order to predict genetic relatedness using

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human mtDNA hypervariable region I sequences and according to the study, ML can be employed as a complementary tool [35]. In identification analysis; Compared to bone tissue and teeth, muscle tissue samples and bone marrow swabs are preferred because these tissues are faster and easier to process [36].

The transfer of muscle tissue to the FTA card from an incision made in the body to be identified can be used for sampling. It is stated that this method is an effective and economical method in identification studies in mass disasters. In addition, a similar method was applied for tsunami victims in 2004 [37].

Human remains preferred in identification studies; soft tissues (skeletal muscle, organ tissues and skin) and blood. Hard tissues (bone and teeth) are the preferred specimens if the corpse is decomposed or if environmental factors exist that would cause the DNA in soft tissue to deteriorate. Samples that can be collected for identification from corpses that have no signs of decay and that have preserved their integrity; blood sample and oral swab sample. The blood sample can be transferred on an FTA card or collected as a swab. However, if a sample is to be taken from a corpse with disrupted body integrity, taking into account that there is no evidence of decay, blood or approximately 1 g of deep red muscle tissue can be taken as a sample [13].

Within the scope of identification of disaster victims, DNA tests can be performed from many different biological materials. If the event is very recent and blood, tooth or bone samples cannot be collected, heart muscle is the most suitable biological material for DNA testing. The analysis can be continued by collecting the heart muscle, which is also very rich in mitochondrial DNA.

Secondary Identification Methods

While primary methods provide an accurate identification, the results of secondary methods are not certain. However, they can be used as supportive methods. Visual identification is one of the secondary identification methods. According to the type and the occurrence form of disaster, visual identification may be used. If there is no deformation on the body, this method can be preferred as a support. But in some disasters, victims can be found beyond recognition. In such cases, it can be very difficult to identify people visually. People often recognize their relatives visually, but in some cases, they may not be able to identify even their closest relatives because they are psychologically affected by the disaster. Due to the psychological trauma they are in at that moment, there may be a problem in identifying the victim. In psychology, this is explained by people's urge not to learn the truth or to reject it [13].

Personal belonging of victims is the other secondary identification method. They can be very important in locating victims in disaster areas. For example, in the event of an earthquake, it is very important to get an idea of who the person is thanks to the belongings next to a person who was removed from the rubble, or it is very important to have an identity on the person.

To give another example, jewelries or physical identification of documents may be used in DVI processes [20]. In some cases, uniforms or similar professional clothes on people will shorten the identification process considerably. Religious clothes or some symbols of religious belief are also important data that will affect the identification process. In addition, reference samples can be collected from the person's belongings to be used in DNA analysis. For example, a person's comb or toothbrush can be good sources of DNA. In addition, used glass-like items (for instance, mugs) or underwear are also sources of medium quality DNA. Although they are weaker sources than others, items such as wrist watches, jewelry or clothes of the person to be identified can also be used as DNA sources [13].

CONCLUSION

Disasters can affect different numbers of people. Identification of victims is much more difficult when the number of affected people is high. Disasters can actualize open air or interior. In general terms, there are four different steps in the DVI process. Depending on the disaster place, methods for identification can change. Field study about disaster areas is one of the most important parts of identification. It is very important that the field analysis is done correctly and that the victims are reached without breaking the integrity. After field work, autopsy and collection of post mortem data takes place. During this process, necessary information for identification can be obtained. Different biological materials and physical determinants are examined. Depending on disaster type, the extent of bodily damage may vary. Therefore, fingerprints cannot be obtained. If fingerprints are in good condition, they are very reliable for identification. In addition, distinctive physical features of people can be used for identification. Third identification method is dental examination. Teeth are one of the most reliable identification methods. The other reliable identification method is DNA analysis. Comparison of DNA samples from victims with family members is a very robust identification method. All of these four mentioned methods are primary identification methods. Therefore, they are very reliable. In addition to them, there are secondary identification methods. Visual identification and personal belongings are in this category.

These methods can be used as auxiliary methods but they are not as reliable as primary identification methods. After autopsy, ante-mortem medical records of a victim are collected in order to use for comparison. Relatives or personal belongings of victims can be used as comparison material for identification. Later, ante-mortem medical records of a victim are compared with their post-mortem findings. As a result, identification of the victim is completed.

Conflict of interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
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Ethical approval
Ethics committee approval is not required.

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References

1. Zecha H, Stavrianos C, Viner MD, et al. Disaster victim identification: An overview. J Forensic Sci. 2019;64:1043-53.
2. INTERPOL Disaster Victim Identification Guide. https://www.interpol.int/en/How-we-work/Notices/View-Disaster-Victim-Identification-Guide access date 06.03.2023
3. Shaluf IM. Disaster types. Disaster prevention and management. An International Journal. 2007;16:704-17.
4. Nuzzolese E, Di Vella G. Future project concerning mass disaster management: a forensic odontology prospectus. Int Dent J. 2007;57:261-6.
5. United Nations. Sendai Framework for Disaster Risk Reduction 2015-2030. https://www.undrr.org/implementing-sendai-framework/sendai-framework-disaster-risk-reduction-2015-2030 access date 02.03.23
6. Ainsworth RJ, Cross PA. Forensic odontology. Br Dent J. 1998;184:393-9.
7. Luntz J. The use of dental records in disaster victim identification. J Forensic Dent Sci. 2018;10:152-6.
8. See KL, Aziz S, Mahmood MS. Beyond DVI: future identification, research and archiving. J Forensic Res. 2016;7:2.
9. Interpol. (2023). Disaster Victim Identification (DVI). Retrieved from: https://www.interpol.int/How-we-work/Forensics/Disaster-Victim-Identification-DVI access date 07.03.2023
10. Hinchliffe J. Forensic odontology, part 1. Dental identification. Br Dent J. 2011;210:219-24.
11. Brough AL, Morgan B, Rutty GN. Postmortem computed tomography (PMCT) and disaster victim identification. Radiol Med. 2015;120:866-73.
12. Leo C, O'Connor JA, McNulty JP. Combined radiographic and anthropological approaches to victim identification of partially decomposed or skeletal remains. Radiography. 2013;19:353-62.
13. Kara U. Disaster victim identification: Organization of forensic DNA laboratory in possible Istanbul earthquake and role of the forensic geneticist. Master's thesis, Istanbul University, Istanbul, 2013.
14. Hutchins LA. Chapter 5: Systems of Friction Ridge Classification. In McRoberts A, ed, The Fingerprint Sourcebook. National Institute of Justice. 2011.
15. Solhi H, Hashemieh M, Nejad MLD, et al. Diagnostic value of fingerprint patterns: an explorative study on beta-thalassemia diagnosis. Bangladesh Med Res Counc Bull. 2010;36:27-31.
16. Phulari RG. Textbook of dental anatomy, physiology and occlusion. JP Medical Ltd. 2013.
17. Utsuno DH. Victim identification in large-scale disasters using dental findings. IATSS Res. 2019;43:90-6.
18. Schuller-Götzburg P, Suchanek J. Forensic odontologists successfully identify tsunami victims in Phuket, Thailand. Forensic Science Int. 2007;171:204-7.
19. Utsuno H, Kanoh T, Tadokoro O, et al. Preliminary study of post mortem identification using lip prints. Forensic Science Int. 2005;149:129-32.
20. Ziętkiewicz E, Witt M, Daca P, et al. Current genetic methodologies in the identification of disaster victims and in forensic analysis. J Appl Genet. 2012;53:41-60.
21. Holland M, Cave CA, Holland CA, et al. 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;44:264-72.
22. Alonso A, Martín P, Albarrán C, et al. Challenges of DNA profiling in mass disaster investigations. Croat Med J. 2005;46:540-8.
23. Turingan RS, Brown J, Kaplun L, et al. Identification of human remains using Rapid DNA analysis. Int J Legal Med. 2020;134:863-72.
24. Morgan OW, Sribanditmongkol P, Perera C, et al. Mass fatality management following the South Asian tsunami disaster: case studies in Thailand, Indonesia, and Sri Lanka. PLoS medicine. 2006;3:195.
25. Moreira AR, Vieira LY, Dias NE, et al. Identification of victims of the collapse of a mine tailing dam in Brumadinho. Forensic Sci Res. 2022;7:580-9.
26. Morling N. Forensic genetics. The Lancet. 2004;364:10-1.
27. Butler JM, Coble M, Vallone P. STRs vs. SNPs: thoughts on the future of forensic DNA testing. Forensic Sci Med Pathol. 2007;3:200-5.
28. Budimlija ZM, Prinz MK, Zelson-Mundorff A, et al. World Trade Center human identification project: experiences with individual body identification cases. Croat Med J. 2003;44:259-63.
29. Yudianto A, Setiawan F. The effectiveness of mini primer STR CODIS in DNA degradation as the effect of high-temperature exposure. Anal Cell Pathol. 2020.
30. Bertoglio B, Grignani P, Di Simone P, et al. Disaster victim identification by kinship analysis: the Lampedusa October 3rd, 2013 shipwreck. Forensic Sci Int: Genetics. 2020;44:102-56.
31. Alakoç YD. Adli bilimlerde DNA analizleri. Ankara Üniversitesi Dikimevi Sağlık Hizmetleri Meslek Yüksekokulu Dergisi. 2010;9:1-8.
32. Carracedo A. Forensic Genetics: History. In JA Siegel, P J Saukko & MM Houck (Eds.). Encyclopedia of Forensic Sciences. 2nd ed., Academic Press. 2013;206-10.
33. Court D S. Mitochondrial DNA in forensic use. Emerg Top Life Sci. 2021;415-26.
34. Ohuchi T, Guan X, Funayama M. Evaluation of the utility of mitochondrial DNA testing in personal identification work in the great east Japan earthquake of 2011. Tohoku J Exp Med. 2021;255:275-81.
35. Govender P, Fashoto SG, Maharaj L. The application of machine learning to predict genetic relatedness using human mtDNA hypervariable region I sequences. Plos one. 2022;17:0263790.
36. de Boer HH, Maat GJ, Kadarmo DA, et al. DNA identification of human remains in Disaster Victim Identification (DVI): An efficient sampling method for muscle, bone, bone marrow and teeth. Forensic Sci Inte. 2018;289:253-9.
37. Watherston J, Watson J, Bruce D. Efficient DNA profiling protocols for disaster victim identification. Forensic Sci. 2021;1:148-70.