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DENTAL IDENTIFICATION AND ASPECTS OF MEDICO-LEGAL INVESTIGATIONS OF THE FINNISH VICTIMS OF THE SUMATRA-ANDAMAN EARTHQUAKE ON 26 DECEMBER 2004

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ACADEMIC DISSERTATION

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Dedicated to the five Finnish nationals that still are missing

ABSTRACT

The Sumatra-Andaman earthquake on 26 December 2004 was the third strongest earthquake ever recorded by seismographic methods. All of the world´s five earthquakes that have reached the value of 9 on the Richter scale have occurred within about the last 60 years. Due to the subsequent strong tsunami, the catastrophe was one of the most destructive in human history.

The dimensions of the tsunami, judged by material destruction and number of human victims, required an immediate response of national and international rescue and victim identification teams.

The identification operation was carried out in Thailand under the leadership of the Ministry of the Interior with the help provided by Interpol and the countries involved.

Interpol has developed and published guidelines for accident investigation. Like the other 187 Interpol member countries, Finland has a national Disaster Victim Identification (DVI) Team organized by the National Bureau of Investigation (NBI). The Finnish DVI Team was founded in 1991.

On 28 December 2004, the Government of Thailand made an official request to Finland for assistance in the identification operation.

The task of the Finnish ante-mortem (AM) DVI team was to collect material for all kinds of identification methods in cooperation with practicing dentists, relatives, health care centers and hospitals.

In Thailand, the members of DVI teams examined dead bodies for dental, medical, fingerprint and DNA post-mortem (PM) data. Comparison of the AM and PM material took place in the Thailand Tsunami Victim Identification-Information Management Centre (TTVI-IMC) in Phuket. After identification, the bodies were delivered for repatriation. The identity of Finnish victims was verified by a dental and external body examination at Phuket Airport before transport to Finland.

The number of Finnish nationals who perished in the disaster was 179. Of them, 174 have been identified and 165 repatriated to Finland, and nine to other countries. Five victims are still missing.

Under the Finnish law concerning examination of the cause and manner of death in accident cases, all victims underwent in Finland a complete medico-legal autopsy including verification of the identification made in Thailand.

Of the 165 victims repatriated, 112 (68%) had sufficient details in their dentitions to establish their identity. Of the adult victims, the dental identification rate was 90% and of children 25%. In Thailand, approximately 43% of all identifications were performed primarily by dental methods.

The Finnish Identification Board confirmed the identification based mainly on fingerprints, DNA, or dental data. No discrepancies existed between the identity results obtained in Thailand and in Finland.

Based on the death certificates signed by the forensic pathologist after the medico-legal autopsy in Finland, the most common cause of death proved to be submersion, for 152 or 92.7% of the victims. Injury was the cause of death in 12 cases (7.3%). Injuries existed in 36 cases as contributing factors for drowning, and in 4 cases for injury-based death.

There is a general agreement as to the success of the identification operation concerning the disaster. In future, international teamwork will be more effective because of the methods of proceedings learned in this operation.

The success of the Finnish forensic odontological branch is greatly based on the even worldwide unique education program established in 1999.

Finnish dental practitioners deserve recognition for the careful filing of records and radiographs that enabled the dental identification of so many Finnish victims.

ABBREVIATIONS

A.B.F.O.	American Board of Forensic Odontology
AM	Ante Mortem (before death)
CoD	Cause of Death
DDPM	Department of Disaster Prevention and Mitigation, Thailand
DVI	Disaster Victim Identification
ENFSI	European Network of Forensic Science Institutes
EU	European Union
GP	Greulich and Pyle age assessment method
HUID	Human Identification software
ICD	International Classification of Diseases
ICMP	International Commission on Missing Persons
ICPC	International Criminal Police Commission
ICPO	International Criminal Police Organization
ICTY	International Criminal Tribunal for the former Yugoslavia
IFRC	International Federation of Red Cross and Red Crescent Societies
Interpol	International Criminal Police Organization
IOFOS	International Organization for Forensic Odonto-Stomatology
M	Magnitude
M_L	Local Magnitude Scale
M_W	Moment Magnitude Scale, MMS
NBI	National Bureau of Investigation, Finland
NCB	National Central Bureau
PM	Post Mortem (after death)
PTWC	Pacific Tsunami Warning Center
RTG	Royal Thai Government
TTVI	Thai Tsunami Victim Identification
TTVI-IMC	Thai Tsunami Victim Identification-Information Management Centre
TW2	Tanner and Whitehouse age assessment method
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USGS	United States Geological Survey
UTC	Coordinated Universal Time
WHO	World Health Organization

Measures

1 foot =	0.30 metre (m)
1 yard =	0.91 m
1 mile =	1609 m

CONTENTS:

INTRODUCTION 8

1. Geological survey of earthquakes and tsunamis 8
   - 1.1. Earthquakes 8
   - 1.2. Tsunamis 9
2. Historical survey of earthquakes and tsunamis 10
   - 2.1. General 10
   - 2.2. China 12
   - 2.3. Finland 12
   - 2.4. Europe 13
   - 2.5. Pacific Ocean 13
   - 2.6. The Andaman, Nicobar, and Sunda islands 14
3. The Sumatra-Andaman earthquake 15
4. Historical survey of human identification 16
   - 4.1. Interpol 16
   - 4.2. Finland 17
   - 4.3. Thailand 17
5. Definitions of disasters and victim identification 18
6. Organizations and tasks in victim identification 19
   - 6.1. General 19
   - 6.2. Victim Identification unit and process of identification 20

AIMS OF THE STUDY 24

SUBJECTS, MATERIALS AND METHODS 25

7. Subjects 25
   - 7.1. General 25

7.2. Thailand 25
7.3. Finland 25

8. Methods 26

8.1. International aspects 26
8.2. Operations in Thailand 27
8.2.1. Thai authority 27
8.2.2. Interpol 27
8.2.3. Organization and facilities 28
8.2.4. Finnish DVI team 30
8.2.5. Ante-mortem data 30
8.2.6. Post-mortem examination 31
8.2.7. Identification 34
8.3. Operations in Finland 37
8.3.1. Events 37
8.3.2. Management of the operation 37
8.3.3. DVI team 38
8.3.4. Legal aspects 38
8.3.5. Collection and availability of dental ante-mortem data. 39
8.3.6. Collection and availability of medical and DNA ante-mortem data 40
8.3.7. Repatriation 41
8.3.8. Investigation of cause and manner of death 41
8.3.9. Verification of the identity 42
8.3.10. Identification board 43

RESULTS 45

9. Dental ante-mortem data 45

9.1. Finland 45

9.2. Thailand and other countries 46

10. Medical, physical and DNA ante-mortem data, Finland 47

11. Post-mortem data 48

11.1. Thailand 48

11.2. Finland 49

12. Identification 50

12.1. Thailand 51

12.2. Finland 54

12.2.1. Repatriation of victims 54

12.2.2. Identification methods and results 57

12.2.3. Dental identification 60

12.2.4. Age assessment 61

13. Cause-of-death investigation in Finland 63

DISCUSSION 73

14. Events 73

15. Tasks and standards of disaster victim identification 74

15.1. Forensic team and investigations 74

15.2. Ante-mortem data 77

15.3. Post-mortem data 80

15.4. Identification 85

15.5. Investigation of cause of death 93

16. Limitations and adverse factors in the identification 95

17. Future outlook 99

SUMMARY 103

ACKNOWLEDGEMENTS 106

LITERATURE 108

INTRODUCTION

1. Geological survey of earthquakes and tsunamis

1.1. Earthquakes

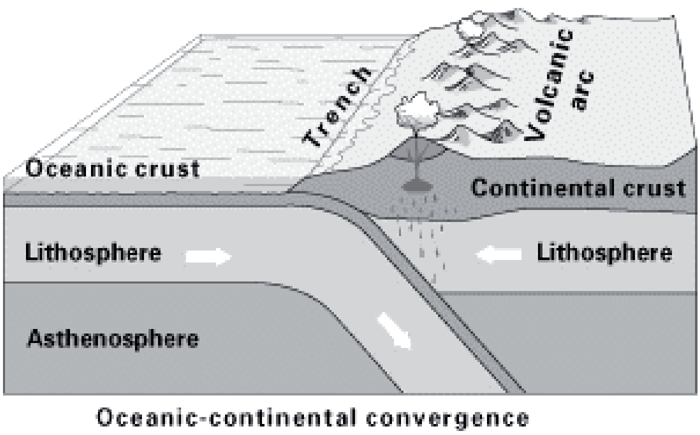
The Earth´s crust of about 500 million square kilometres is fragmented into dozens of plates including seven major ones that constitute 94% of the total area of the litosphere (Anderson 2002) and seven notable minor plates. They move in relation to one another 2.5 to 15 centimeters per year (United States Geological Survey, USGS 1999 [1]). New crustal material develops from the magma in spaces between plates moving away from each other. These divergent boundaries exist mostly in the oceanic ridge systems. According to generally accepted opinion of the plate movement (USGS 1999 [2], Encycl Brit Online 2009 [8]), the older part of the oceanic litosphere becomes denser and sinks deeper into the underlying asthenosphere. In convergent motion, the more dense oceanic plate colliding with the continental plate descends beneath it producing friction that may discharge as an earthquake. Deeper, the high temperature melts the subducting edge of the plate, producing magma and gases that arise as volcanism on the coastal continental crust as illustrated in Figure 1.

Earthquakes occur mostly in three large zones: The first includes the coast of the Pacific Ocean, the boundary areas around the Pacific Plate, where 70 to 90% of the total seismic energy is released. The second zone, the Alpide belt, extends from Java and Sumatra through the Himalayas and the Mediterranean to the Atlantic Ocean. The third zone follows the Mid-Atlantic ridge (USGS 2008 [3], Encycl Brit Online 2007 [1]).

A scale to represent the force of earthquakes, recorded on a standard seismograph was set up in 1935 by Charles Richter (Encycl Brit Online 2009 [2]). According to the USGS (2004 [16]), in this logarithmic local magnitude scale (M_L) a rise of one unit means an earthquake ten times as strong, releasing about 31 times as much energy. In 1979 (Hanks and Kanamori 1979), a new scale was developed in order to take advantage of the great number of globally positioned seismograph stations. Like the Richter scale, the moment magnitude scale (MMS, M_W) is logarithmic and estimates the energy released by the earthquake. Moment magnitude has been applied to estimate magnitudes of medium (> 3.5) and large (> 7) earthquakes.

The average annual occurrence of earthquakes of magnitude eight or more is only one, while quakes of value three or less occur annually about 1 300 000 times. About 50 000 earthquakes can be detected without seismographs, and 100 are strong enough to produce damage (Encycl Brit Online 2007 [1]).

Figure 1.Subduction processes in oceanic-continental convergence resulting in formation of earthquakes and volcanic activity (USGS 2009 [4]). (With permission of the USGS).



1.2. Tsunamis

The word "tsunami" originates from Japanese, meaning "harbor wave" from a situation in which seamen returning from a calm sea found their harbor destroyed by surges. A tsunami is a surge caused by an earthquake, volcanic eruption or landslide that disturbs the stability of a mass of water. It would be possible to create tsunamis by nuclear explosives or accidental explosions. The quantity of released energy caused by an earthquake underneath the sea depends on the magnitude, the width of the movement area, and the depth of the water. The height of the wave depends on the depth of the water. On the open sea, as in the Indian Ocean, where the 2004 Sumatra-Andaman earthquake occurred at a depth of 4 000 meters, the height of the tsunami wave was only 60 centimeters (Major Accident Investigation Committee 2005). The length of the wave can be great, even 200 kilometers, and the speed 500 to 1 000 km/h (Geist et al 2006). In shallow water, as its speed decreases, its energy forces the wave reach a height of even 20 to 30 meters above mean sea level (Encycl Brit Online 2009 [1]). Requirements for a destructive tsunami are a strong earthquake (M over 7), a marked vertical and longitudinal movement of the seafloor, and a large mass of water to displace.

2. Historical survey of earthquakes and tsunamis

2.1. General

The history of mankind knows several destructive earthquakes. The magnitudes of the oldest disasters have later been estimated based on written descriptions of the extent of damage and number of human victims. A systemic follow-up study of earthquakes was made possible by the development of the local magnitude scale in 1935 by Charles Richter, and the horizontal pendulum seismograph after the Second World War (Encycl Brit Online 2009 [3]). Table 1 presents some earthquakes and volcanic eruptions that have been significant due to the strength, number of victims, or influence on the environment. Remarkable is the small number of victims in three of the four strongest earthquakes ever measured. The distant position of the epicentre and the Tsunami warning system in the Pacific Ocean have kept damage relatively small.

Table 1. Estimated numbers of human victims in some convulsions of nature caused by earthquakes and volcanic eruptions (Explanations provided in the text)

Location	Year	Magnitude	Number of victims	Particulars
China	1556	8.0	830 000	Most fatalities in history
Portugal, Lisbon	1755	8.7	70 000	Destructive tsunami and fire
Indonesia, Mount Tambora	1815	-	90 000	Largest volcanic eruption in recorded history. Global climatic effects
Indonesia, Krakatau	1883	-	36 000	Volcanic eruption. Climatic effects, destructive surges
Italy, Messina	1908	7.2	72 000	Strong tsunami. Even 110 000 estimated fatalities
Russia, Kamchatca	1952	9.0	-	Environmental damage, no human victims
Chile	1960	9.5	1 655	Strongest earthquake in recorded history
Alaska, Prince William Sound	1964	9.2	128	Second strongest earthquake
China, Tangshan	1976	7.5	242 000	Possibly 655 000 victims. Then most fatalities in modern history
Indonesia, off Sumatra	2004	9.1	230 000	Third strongest earthquake, deadliest tsunami in history
Haiti	2010	7.0	316 000	1.5 million survivors homeless
Japan, Tohoku earthquake	2011	9.0	28 000	Strong tsunami, serious environmental hazards

2.2. China

According to the USGS, the earliest known earthquake occurred in China in 1831 BC in Shandong province. China also suffered the catastrophe with the most fatalities ever in 1556 (AD). It claimed about 830 000 victims. The magnitude of this earthquake has been estimated as eight. In 1920 an earthquake (M 7.8) in Ningxia Autonomous Region killed 200 000 people. A similar number of victims died in an earthquake (M 7.6-7.9) seven years later in Tsinghai. An earthquake of 7.5 took place on July 1976 in Tangshan, officially reported killing 242 000 persons. This industrial city was almost completely destroyed. The number of victims is estimated to even 655 000 thus being the most fatalt earthquake disaster in modern history. (Encycl Brit Online 2007 [1]).

In 132 AD, a chinese scientist Chang Heng, invented the first seismoscope, an instrument that could register the shaking caused by an earthquake and show its direction (Encycl Brit Online 2009 [3]).

2.3. Finland

Observations of earthquakes exist over a period of 400 years. The Geographical Society of Finland (Suomen maantieteellinen seura) started systematic collection of information on earthquakes in 1880. Historical documentation changed in 1924 to the more exact seismograph-based method by means of two Mainka-seismographs at the Department of Physics of the University of Helsinki (Department of Geosciences and Geography, University of Helsinki 2006 [1]).

In Finland, annually 10 to 20 earthquakes occur at a magnitude of less than four, causing no significant damage. The strongest one, magnitude about five, took place on 23 June 1882 in the Gulf of Bothnia, western Finland (Department of Geosciences and Geography, University of Helsinki 2006 [2]). According to another source of information (Geophysical Observatory, University of Oulu 2007), the strongest, magnitude 4.7, occurred on 4 November 1898 in Tornio. The strongest earthquake (M 3.8) in the seismographic period took place on 17 February 1979 in Alajärvi, Pohjanmaa (Department of Geosciences and Geography, University of Helsinki 2006 [3]).

The origin of these earthquakes is the divergent movement of the Eurasian and North American plates in the Mid-Atlantic ridge.

2.4. Europe

The southern part of Europe belongs to the seismic Alpide belt. The northwards moving African plate is colliding with the Eurasian plate in the Mediterranean area.

Europe's most powerful earthquake, estimated magnitude 8.7, occurred in 1755 in Lisbon, Portugal. Collapsing buildings, fires, and great tsunami waves claimed more than 60 000 human victims. Within 10 hours, waves four meters high reached Martinique in the Caribbean Sea (Encycl Brit Online 2007[4]).

In the Mediterranean area, the oldest known catastrophe was the volcanic eruption of Santorini, occurred in some year between 1627 and 1600 BC, located on the island of Thira in the Aegean Sea. It is known also as the Minoan eruption, or the late Bronze Age eruption. It devastated not only Santorini, which according to many scientists might be the origin of the Atlantis legend, but had a strong impact on the whole eastern Mediterranean. The eruption also generated high tsunami-like surges. Possibly it influenced global climatic conditions (Friedrich et al 2006, Volcano Discovery 2007).

In Messina, Italy, in 1908, an earthquake of 7.2 to 7.5 on the Richter scale with strong tsunami waves claimed 72 000, possibly even 110 000 victims (USGS 2010 [5]).

The magnitude of an earthquake near Svalbard (Spitzbergen) in Norway on 21 February 2008 was estimated at 6.2 and therefore is considered the strongest ever in northern Europe.

2.5. Pacific Ocean

In the Circum-Pacific seismic belt occur more than 80% of the largest earthquakes and 85% of the tsunamis (Geist 2006). Four of the five strongest earthquakes ever measured by seismograph have taken place on different sides of this area. The strongest one, magnitude 9.5, occurred in 1960 in Chile, killing 1655 people (USGS 2007 [6]). An earthquake of 9.2 occurred in 1964 in Prince William Sound, Alaska, claiming 128 victims (USGS 2007 [7]). In 1952, a size 9.0 earthquake took place off the Kamchatka Peninsula in Russia. No human lives were lost, but tsunami waves were observed in Alaska and Hawaii, causing great material damage (USGS 2007 [8]). The most powerful known earthquake in Japan, magnitude 9.0, called the Great East Japan or Tohoku earthquake, occurred on 11 March 2011 near the northeast coast of Honshu (USGS 2011 [13]). This earthquake took place approximately 70 km from the nearest point on Japan's coastline, where tsunami waves hit in 10 to 30 minutes.

The great vertical differences between high mountains and deep ocean trenches have been considered the cause of the seismic activity within the Circum-Pacific belt. Due to the often occurring tsunamis, the Tsunami Warning Center (PTWC) was founded in 1949 in Hawaii. "In the aftermath of the 2004 Indian Ocean tsunami, the PTWC has taken on additional areas of responsibility including the Indian Ocean, South China Sea, Caribbean Sea, and Puerto Rico & the U.S. Virgin Islands" (PTWC history 2007).

The highest surge, 520 m, ever caused by an earthquake (magnitude 7.9), developed in Lituya Bay, Alaska, in 1958, when a massive rock of 40 million cubic yards crashed down into a narrow bay. Only two persons died (Pararas-Carayannis 1999).

2.6. The Andaman, Nicobar, and Sunda islands

The India Plate, a part of the Indo-Australian Plate located off Thailand's western coast, is subducting beneath the minor Burma Plate that is a separated part of the great Eurasian Plate. The Andaman Islands, Nicobar Islands, and the northern part of Sumatra are located on this plate.
The boundary area shows its activity by earthquakes and volcanoes. The eruption of the volcano Mount Tambora on Sumbava Island in 1815 has been considered the strongest in history (USGS 2003 [9], Encycl Brit Online 2009 [4]). Its explosive eruption and surges caused by pyroclastic flows killed 10 000 people directly, and from hunger and diseases 82 000.

In the Sunda Strait between the islands of Java and Sumatra, eruptions have occurred repeatedly throughout history. The most wellknown was the eruption of Krakatau in 1883. Two thirds of the island collapsed beneath sea level. This, in combination with the explosion, produced tsunami-like waves of which the largest reached 30 to 40 meters above sea level. The hot pumice clouds 80 km high, pyroclastic flows, and surges killed 36 000 people (USGS 2004 [10], Encycl Brit Online 2009 [5]). The eruptions of Mount Tambora and Krakatau caused global climate effects, due to the resultant clouds that cooled the earth's temperature.

"The Sumatran section of the Sunda megathrust generated great earthquakes south of the 2004 event in 1797, 1833, and 1861, but there is no historical record of giant earthquakes to the north, between Sumatra and Myanmar" (Subarya et al 2006). Earthquakes in the area of the Nicobar and Andaman Islands occurred in 1881and 1941 (M 7.9), but no historical records describe previous great tsunamis in the Bay of Bengal (Lay et al 2005).

3. The Sumatra-Andaman earthquake

The strong earthquake that occurred on 26 December 2004 at 00:58:53 UTC (Coordinated Universal Time) (7:58:53 Bangkok and Jakarta time) off Sumatra Island beneath the sea floor of the Indian Ocean, is known as the Sumatra-Andaman earthquake. Its magnitude, 9.1 (M_W) (Lay et al 2005, Subaraya et al 2006, USGS 2009[11]), was the third strongest ever measured, and the strongest in the previous 40 years (Park et al 2005, Vigny et al 2005). The distance between the epicenter of the earthquake beneath the Indian Ocean and the coast of the northern part of Sumatra Island, Banda Aceh of Indonesia, was 250 kilometers. The main shock occurred at a depth of about 30 kilometers (Lay et al 2005). The displacement of the earth's crust was 1 200 to 1 300 kilometres long and reached vertically several meters high. The vertical movement displaced hundreds of cubic kilometers of sea water above the normal level (Geist et al 2006). The released energy moving as waves at over 500 km per hour in the 4 000-m deep water needed less than half an hour to reach the coast of Sumatra, and about 100 minutes (United Nations Thailand 2008), the coast of Thailand. Near the coast in the shallow water the waves became higher, hitting the beach as tsunamis even nine meters high. In 11 hours, the tsunami ran a distance of 8 000 kilometers to South Africa, the most distant location reporting a tsunami-caused death (Geist et al 2006). Waves were observable even in northern parts of the Atlantic and Pacific Oceans (Such a global influence was observed once previously when Krakatau erupted in 1883). The catastrophe claimed at least 225 000 victims in 12 countries (Encycl Brit Online 2011 [6]). According to Interpol, the number of countries was 13: the Indian mainland counted separately from India's Andaman and Nicobar Islands. More than two million people remained homeless. Measured in human victims this was one of the most destructive earthquakes in recorded history, as well as the deadliest tsunami ever.

4. Historical survey of human identification

In his article concerning the history of forensic dentistry, Luntz (1977) describes how Agrippina, the wife of the Roman Emperor Claudius (AD 1-54), demanded to see the decapitated head of his mistress, who was known to have an anterior tooth discolored or in malposition (also Encycl Brit Online 2007 [7]). According to another history (Eckert 1992), the Emperor Nero, A.D. 66, murdered his wife and presented her head on a dish to his mistress Sabina who identified her by a black anterior tooth.

King William the Conqueror (circa 1066 AD) used to seal his mail by biting into the soft sealing wax (Luntz and Luntz 1973).

In 1775, Dr. Joseph Warren who was killed during the battle of Bunker Hill, was identified by his friend Paul Revere by means of a denture, a silver and ivory bridge that Revere had made (Eckert 1992). Eckert (1992) also describes the first time dental evidence was accepted in a U.S. court, in 1849. Dr. George Parkman, a professor at Harvard University, was killed, the body partially burned and dismembered. A fragment of tooth fused to gold was found. The dentist who had constructed the denture testified, and his evidence was enough for the jury to bring in a verdict.

Hutt (2003) has described the birthdate and place of forensic odontology, which has been considered to be the 4th of May 1897 in Paris, when the Bazaar de la Charitè was burnt down totally, claiming 140 (official count 124) victims. Dr. O. Amoedo, a native Cuban dentist, took part in the identification of victims, and thereafter was considered the founder of forensic odontology through his publication entitled *L'Art Dentaire-En Medecine Legale* (Luntz 1977).

4.1. Interpol

The first International Criminal Police Congress took place in 1914 in Monaco with participants from 14 countries. Creation of the International Criminal Police Commission (ICPC) occurred in 1923 in Vienna, Austria. After World War II, the rebuilding of the organization started in 1946 under the leadership of Belgium, with the headquarters set up in Paris. The United Nations granted the

ICPC consultative status as a non-governmental organization in 1949. The ICPC became in 1956 the International Criminal Police Organization-Interpol, abbreviated to ICPO-Interpol (ICPO 2007) or Interpol. The General Secretariat moved to Lyon, France, in 1989 (ICPO 2007). Interpol published in 1984 guidelines for accident investigation in the “Interpol Manual on Disaster Victim Identification” (Interpol 2007 [1]). The 1997 revised manual “Disaster Victim Identification Guide” has been circulated to all Interpol member countries. A new DVI Guide (Interpol 2010 [2]) has since 2010 been published on the Internet sites of Interpol.

Each Interpol member country, 188 in number (2010) of the 196 countries of the world (Rosenberg 2011), has a National Central Bureau to be the official contact with the General Secretariat and other members.

4.2. Finland

The Finnish Disaster Victim Identification (DVI) team was established by order of the Ministry of the Interior in 1991 under the leadership of the Finnish National Bureau of Investigation (NBI). The activity, in practice, had already started in 1989. Its first major task was the identification of victims of the *Estonia* ship disaster on 28 September 1994. Of the 989 passengers and crew members from 17 countries, 94 bodies were found and identified (Joint Accident Investigation Commission of Estonia, Finland and Sweden 1997, Socialstyrelsen, Sweden 1997, Soomer et al 2001).

The operational procedures of the Finnish DVI Team have always been in accordance with the Interpol DVI guidelines. According to the NBI, the DVI team consists of personnel of the NBI participating in DVI work besides their regular jobs, forensic pathologists and odontologists, autopsy technicians, and their deputy members. For debriefing, the team includes a Lutheran priest and a psychologist.

4.3. Thailand

According to information collected by the International Federation of the Red Cross and Red Crescent Societies (IFRC 2005), the primary disaster legislation in Thailand is the Civil Defence Act issued in 1979. It covers all kinds of disasters, prescribes clearly the jurisdiction and responsibilities of the organizations concerned, and also includes a systematic process of disaster management. Department of Disaster Prevention and Mitigation (DDPM) was established 2002 under the umbrella of the Ministry of the Interior to take responsibility for the disaster management of the country.

In Thailand, a forensic investigation is required in deaths occurring in mass disasters. In general, the purpose of the investigation is to identify the victims and to determine the time and place of death along with the cause and manner of death. Every disaster in Thailand will be under the responsibility of the DDPM (Sribanditmongkol et al 2005).

James (2005) and Petju et al (2007) report that prior to the Southeast Asian tsunami disaster, forensic dentistry in Thailand had played only a minor role in the forensic sciences, and no national standards or guidelines had been established. According to Interpol, there existed no DVI expertise in Thailand before the tsunami catastrophe. According to the James group (2005), only a few forensic pathologists and one forensic odontologist served in the organization of the Royal Thai Police Force that was in charge of victim identification.

5. Definitions of disasters and victim identification

A mass disaster is an unexpected large-scale natural or man-made event causing death or injury, and often including environmental damage. Many kinds of events can lead to disasters, such as convulsions of nature, fires and explosions caused by accidents or criminal acts, even large traffic accidents. Open and closed forms of disasters can be distinguished. An open disaster is a catastrophe resulting in deaths of unknown individuals of an unknown number. In a closed disaster, the number and names of the persons involved are principally known, for example, victims being on a passenger list in an aircraft accident. Many disasters are combinations of these two forms.

One purpose of the identification according to the NBI is to establish the identity of the victim in order to pronounce him or her dead. Identification means a process that determines the names of the deceased by methods that reveal their personal characteristics to compare with data on persons reported missing within the catastrophe concerned.

Any information that can help to distinguish one person from other victims is valuable. According to Interpol, methods have been classified as primary and secondary based on their reliability. The primary means of identification include comparative fingerprint, dental, and DNA analysis, and as a new alternative any *unique medical condition* that consists of physical characteristics, inborn or caused by disease or medical treatment. Personal property, such as jewelry, clothing, and documents in the victim's possession belong among secondary evidence, which may be valuable to confirm the identification and to give the first suggestions of the identity.

The information received concerning the missing person is called ante-mortem (AM) data. Comparative AM data can usually be obtained more quickly in cases of closed disasters.
Post-mortem (PM) data comprise the evidence collected in the forensic investigation from the dead body.

The DVI Guide (Interpol 2010 [2]), in Chapter 4, states that it is necessary to collect and document all available information, both AM and PM, because it is impossible to know in advance what kind of data can be obtained from bodies, and what information for purposes of comparison from missing persons. The method of choice depends not only on the type of accident or event, but also on the condition of individual victims. For identification, there must be readiness for expertise of all kinds of methods (Ludes et al 1994).

For the identification, AM and PM data are compared to reveal similar characteristics. The identity is *established*, if there is an absolute certainty of the identity. The identification result is *probable* if the characteristics correspond, but evidence is insufficient among the AM or PM data to guarantee the individuality. The result is *possible* if the data from the dead body and the missing person lack both personal characteristics and contradictions. *Exclusion* exists when the AM and PM evidence prove to disagree when compared. In the absence of AM or PM data no comparison can be made.

6. Organizations and tasks in victim identification

6.1. General

Increased traffic due to growing internationality has enlarged the risk for mass disasters. Examination of natural and man-made catastrophes becomes more complicated because the victims may represent several nationalities. The country in which the disaster occurs has the responsibility for the rescue and identification operations. It is, however, recommended to act directly or through Interpol with the governments of countries concerned. In addition, to obtain AM information, each country may, with the permission of the government of the country involved, send experts to participate in the identification operation. The Interpol guidelines state that in the tasks concerning identification, and the examination of cause and manner of death, religious and cultural rules and customs are worthy of consideration. They cannot, however, displace the regulations of local (in Finland: Act of the inquest into the cause of death / Laki kuolemansyyn selvittämisestä 459/1973) and international laws. Interpol has developed the idea of uniform standards for disaster investigation. It recommends that each member country establish one or more permanent disaster victim identification teams. They should have the responsibility not only for disaster response, but also for the planning, and for training of the key personnel.

6.2. Victim Identification unit and process of identification

The organization of the victim identification unit recommended by Interpol consists, besides those in command, also of teams with various tasks. In most cases of disasters, the police, in Finland local or from the NBI, assume the command responsibility of the whole operation.

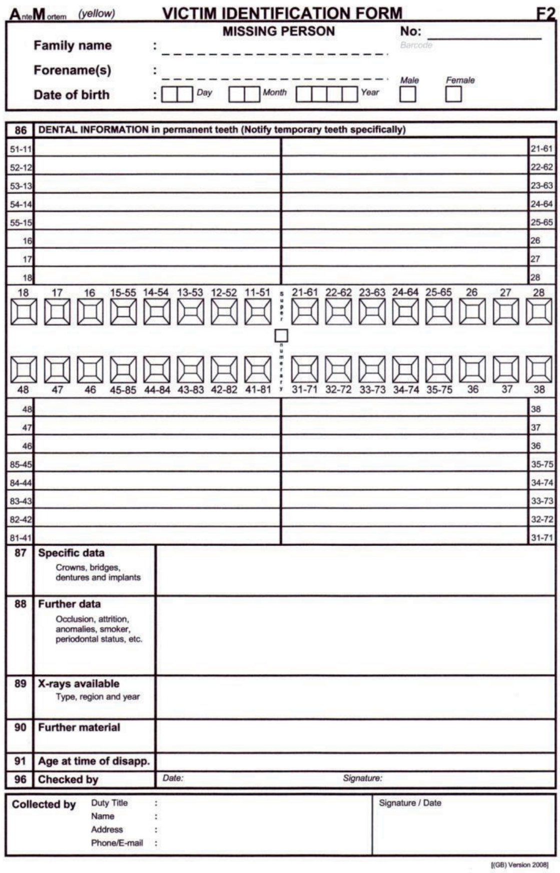
The heads of the DVI team, including forensic pathologists and police officers, should as early as possible be sent to the scene to evaluate the situation. The estimated duration of the operation, the type of the disaster, and the number and condition of the victims have an influence on the number of experts and the specialties to be mobilized.

According to the new Disaster Victim Identification Guide (Interpol 2010 [2]) "the Recovery and Evidence Collection Team is responsible for the recovery of bodies at the disaster site and the collection and preservation of evidence and property at the site as well as the personal effects of victims within the extended area around the disaster site." As team members of this operation, the police may call up various specialists such as forensic pathologists, odontologists, and anthropologists who are trained to recognize and differentiate human tissue fragments. The recovery of bodies or body parts and the preservation of evidence found at the disaster site represent the first steps in the victim identification process.

The members of the Ante Mortem Team collect life-time data for the identification. This includes samples for DNA analysis, fingerprint, and dental comparisons. Additionally, all physical characteristics as well as belongings supposed to have been with the missing person during the accident are registered on the yellow Interpol Disaster Victim Identification forms.

The task of the forensic AM dental team is to analyze the information from patient records, radiographs, plaster models, and photographs, and to store them on DVI forms F1 and F2 (Figure 2), and possibly in computer identification software.

Figure 2. Interpol AM form F2 for dental information



AnteMortem (yellow) **VICTIM IDENTIFICATION FORM** **F2**

MISSING PERSON **No:** ____________ Barcode

Family name : ____________________

Forename(s) : ____________________

Date of birth : [ ][ ] Day [ ][ ] Month [ ][ ][ ][ ] Year Male [ ] Female [ ]

86	DENTAL INFORMATION in permanent teeth (Notify temporary teeth specifically)		
51-11			21-61
52-12			22-62
53-13			23-63
54-14			24-64
55-15			25-65
16			26
17			27
18			28

18 17 16 15-55 14-54 13-53 12-52 11-51 | 21-61 22-62 23-63 24-64 25-65 26 27 28

48 47 46 45-85 44-84 43-83 42-82 41-81 | 31-71 32-72 33-73 34-74 35-75 36 37 38

48			38
47			37
46			36
85-45			35-75
84-44			34-74
83-43			33-73
82-42			32-72
81-41			31-71

87	**Specific data** Crowns, bridges, dentures and implants	
88	**Further data** Occlusion, attrition, anomalies, smoker, periodontal status, etc.	
89	**X-rays available** Type, region and year	
90	**Further material**	
91	**Age at time of disapp.**	
96	**Checked by**	Date: Signature:

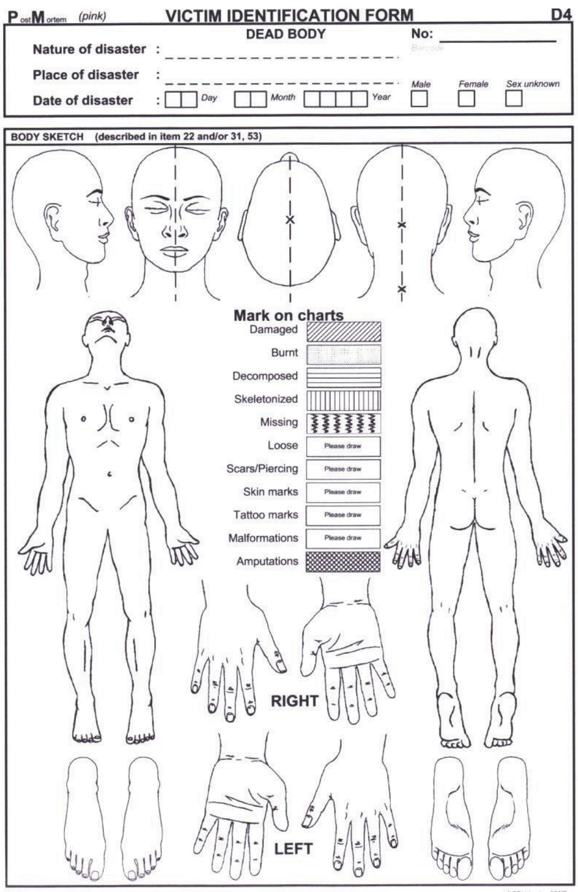
Collected by Duty Title : Name : Address : Phone/E-mail : Signature / Date

[(GB) Version 2008]

For identification purposes, the Post Mortem Team collects all forensic data available from the bodies of victims. The team comprises experts in the fields of fingerprint analysis, forensic pathology, forensic odontology, and DNA analysis (Interpol's DVI Guide 2010[2]). All findings are registered on the pink Interpol DVI forms, starting with the recovery of the body from the scene. Clothing and personal effects such as jewelry are registered by the police. Registration of physical description is performed in connection with the forensic external body investigation (Figure 3). The internal investigation includes, besides the study of the cause of death, also collection of medical personal characteristics, such as changes caused by diseases or medical treatment. All material and findings are photographed in connection with the investigation.

The forensic dental study consists of a clinical examination supplemented with radiographs and photographs. The information is collected on the PM F1 and F2 forms and into the corresponding software.

Figure 3. Interpol PM form D4 for external body investigation



PostMortem (pink) VICTIM IDENTIFICATION FORM D4

DEAD BODY

No:

Nature of disaster :

Place of disaster :

Date of disaster : Day Month Year

Male Female Sex unknown

BODY SKETCH (described in item 22 and/or 31, 53)

Mark on charts

Damaged

Burnt

Decomposed

Skeletonized

Missing

Loose — Please draw

Scars/Piercing — Please draw

Skin marks — Please draw

Tattoo marks — Please draw

Malformations — Please draw

Amputations

RIGHT

LEFT

The Reconciliation Team is responsible for comparison of the AM and PM data (Interpol 2010 [2]). The dental comparison may be performed manually or assisted by computed software like the DVI System International recommended by Interpol. If the comparison leads to a positive identification, the leader of the team submits the corresponding documents to the Identification Board for review and a final decision.

The Identification Board is a group of experts comprising, in Finland, besides a commanding police officer also members trained in forensic medicine, odontology, and police work. The board assembles at regular intervals or by agreement to discuss and verify proposals. The board makes final decisions regarding the suggested identifications submitted by the Reconciliation Team and certifies these decisions on the DVI form. After a positive decision, the victim may be released to relatives for funeral proceedings.

According to Interpol (2010 [2]) "The Care and Counselling Team provides medical and psychological care and counselling for personnel of the Recovery, Evidence collection and Victim Identification unit. The team is also the point of contact for relatives of disaster victims within the context of family assistance".

AIMS OF THE STUDY

The aim of the study was to use the following knowledge collected during the identification operation for victims of the Sumatra-Andaman earthquake to better understand the limitations and to improve the manner of proceedings in dental identification.

Questions requiring answers:

1. What kind of methods were applied in victim identification?

2. What was the predicted rate of success of the dental identification based on ante mortem data compared to the final identification?

3. What differences emerged between adult and child victims concerning identification and injuries?

4. What were the limitations of the dental identification?

5. What were the causes of death of the Finnish victims?

SUBJECTS, MATERIALS AND METHODS

7. Subjects

7.1. General

The estimated number of victims of the Sumatra-Andaman earthquake 2004 reported by the International Federation of the Red Cross and Red Crescent Societies (IFRC 2005) in May 2005 was 226 415, including 176 459 dead and 49 956 missing persons. Besides these, 400 to 600 people are believed to have perished in Myanmar (IFRC 2005). Based on many sources of information, the probable number of victims is established to be between 220 000 and 230 000. Deaths occurred in 12 coastal states of the Indian Ocean (Encycl Brit Online 2011 [6]).

7.2. Thailand

According to the report of the IFRC (2005), "Thailand's population is nearly 66 million people. People of Thai ethnicity make up 80% of the population, with Chinese and Malay groups comprising the other main ethnic identities. In 2004, Thailand acknowledged that over 188 000 refugees and migrant workers from Myanmar contribute significantly to the labour economy." The
Tourism Authority of Thailand (2007) reports that the number of international visitors in 2004, 11.65 million, decreased by 1.51 % in 2005.

According to the Interpol Tsunami Evaluation Working Group (2010), of the 5 395 fatalities in Thailand, approximately 2 400 were foreign nationals from 36 different nations.

7.3. Finland

Statistics Finland (Tilastokeskus 2009) reports that the number of lengthy trips (more than four nights) to Thailand by Finnish nationals (age 15-74 years) was 65 000 in 2004 and 88 000 in 2008. According to the report of the (Finnish) Major Accident Investigation Committee (2005), the number of travel agency customers in Thailand on 26 December 2004 was 2 353, and of independent tourists approximately 300. Less than 200 persons were long-time inhabitants. Weekly, during the high season (2004), approximately 5 000 Finnish nationals visit the popular tourist centers of Khao Lak and Phuket.

Every year, 300 to 500 Finnish nationals die abroad of various causes, accidents representing a minority. According to the Ministry for Foreign Affairs, the number of deaths in 2008 was 328, of which 29 occurred in Thailand.

Afer the tsunami, the Ministry of the Interior published the list of missing Finnish persons on the web site of the National Bureau of Investigation on 30 December 2004. The list including 263 names fell, within a few days, to a final count of 178. Of the Finnish nationals, 177 perished in Thailand and one in Sri Lanka. Additionally, one man perished after the evacuation in a hospital in Finland. Of the 172 missing persons living in Finland, 112 were adults and 60 children less than 18 years of age.

8. Methods

8.1. International aspects

A very significant matter within a disaster like the tsunami catastrophe concerning many countries is that the rescue and victim identification procedures start quickly, and the procedures are familiar and common.

The country in which the disaster occurs has the responsibility for the rescue and identification operations in cooperation with Interpol and the governments of the countries concerned. In addition to obtaining AM information, each country may with the permission of the government of the country involved send experts to participate in the identification operation. Each Interpol member country has a National Central Bureau to be the official contact point for the General Secretariat and other members; Finland has its National Bureau of Investigation (NBI).

8.2. Operations in Thailand

8.2.1. Thai authority

Every disaster occurring in Thailand will fall under the responsibility of the Department of Disaster Prevention and Mitigation (DDPM) under the Ministry of the Interior. The scale of destructive effects of the tsunami waves caused by the Sumatra-Andaman earthquake, however, exceeded all expectations of the Thai government. Problems arose from the lack of a central command center and a national mass fatality plan (Sribanditmongkol et al 2005). On 29 December 2004, the DDPM provided guidelines for the management of dead bodies. The victim identification operations in five provinces were under the control of the Royal Thai Police. Phang Nga province, where 78% of the deaths occurred, was the responsibility of the Forensic Science Institute, Ministry of Justice (Sribanditmongkol et al 2005).

On 12 January, the Thai authorities and Interpol set up the Thai Tsunami Victim Identification (TTVI) operation to assist in the identification of all victims without any discrimination by race or ethnicity, in order that all victims could be returned to their families.

8.2.2. Interpol

According to report called "Interpol's operational response to the tsunami disaster" (Interpol 2006 [3]), the Southeast Asian Tsunami disaster started the biggest single identification operation in Interpol's history. On the morning of the disaster, the Command and Coordination Centre contacted the affected countries to offer Interpol's assistance. Interpol alerted its network of national disaster victim identification teams to inform them of the situation. An Incident Response Team was sent to Thailand to assess the situation and to plan the manner of proceeding.

On 5 January, Interpol convened an emergency international meeting in Lyon, with 26 countries, to discuss the coordination of international DVI teamwork. As a direct result of this meeting, an international Crisis Support Group was formed at the General Secretariat with start-up assistance from the United Kingdom. It consisted of Interpol staff and officials from member countries.

Teams working in the disaster areas applied the internationally accepted Interpol DVI protocol, which enabled officials from all over the world to use the same criteria and compare data in the most effective way.

The key function of the teams of Interpol officers in Thailand was to collect AM and PM DVI information from national teams and feed it into a central database for matching and subsequent identification. The Interpol teams also helped to exchange the information between national liaison officers and DVI teams, and acted as the first point of contact for Interpol countries affected by the tsunami disaster (Interpol 2006 [3]).

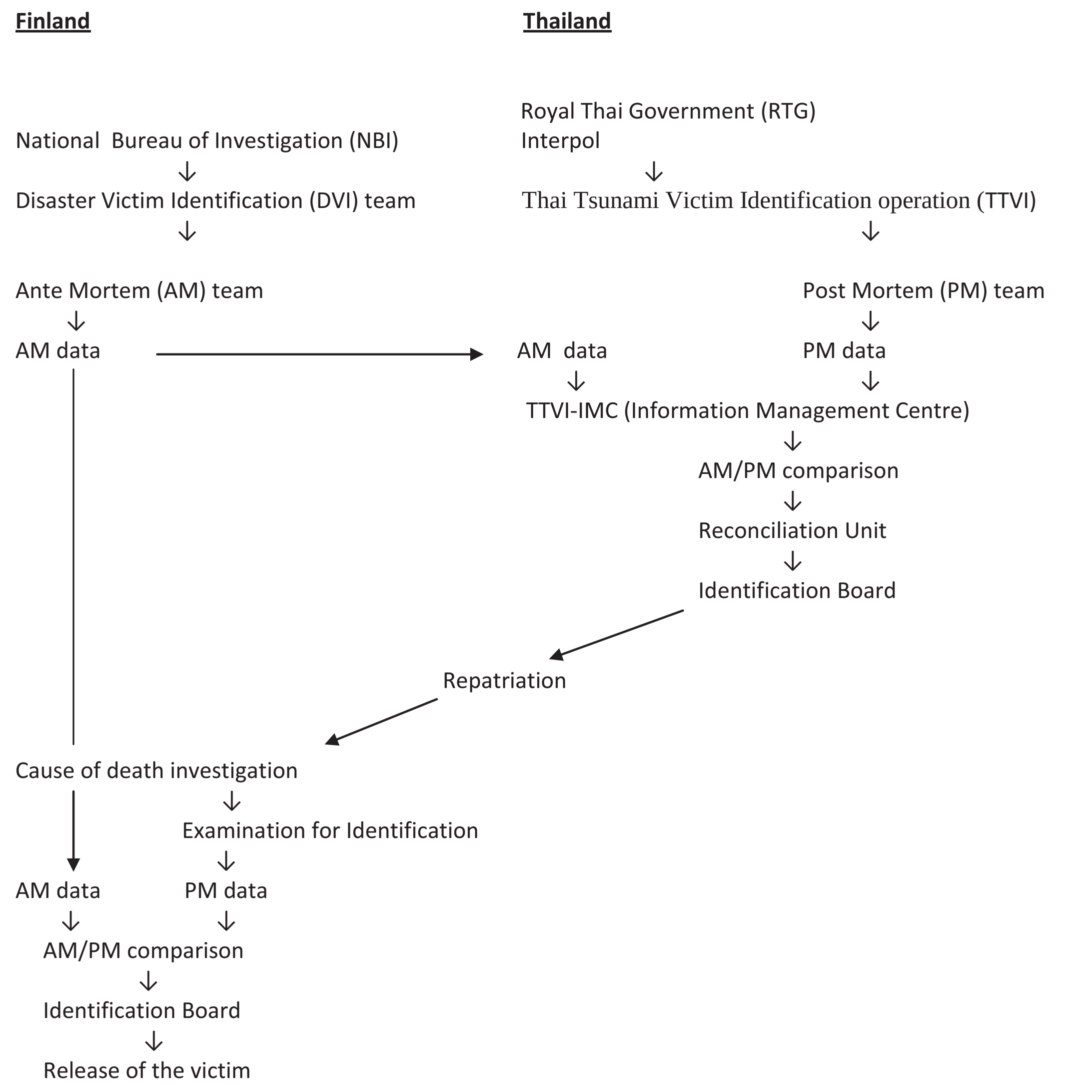
8.2.3. Organization and facilities

In the early phase, the recovery of dead bodies was managed by local governments and carried out by military and volunteer rescue teams. Temporary morgues were set up, mostly in local Buddhist temples. During January 2005 an examination site (body collection center) was established both in Phuket and Krabi, and five sites in Phang Nga: two of them in Takua Pa (Sribanditmongkol et al 2005). On 29 January, a removable field hospital in Phuket (Mai Khao Cemetery or Site 2) was completed by the Norwegian Normeca AS and financed by the Government of Norway.

On the disaster day, the Prime Minister of Thailand, as the leader of the whole international identification organization, sent navy vessels for search and rescue operations, and the Ministry of Public Health called to action more than 100 rescue teams and set up a Rescue Center in Phuket.

On 7 January 2005, a strict protocol for DVI operations was established. On January 12, the Thai Tsunami Victim Identification (TTVI) operation was established formally by the Royal Thai Government (RTG) together with Interpol. The contract included an agreement to use the Interpol DVI Guidelines in the identification procedures. The Telecommunications Organization Thailand Company gave up a part of its office building in Phuket with its facilities for the identification procedure. Those working in the building included police investigation teams, Interpol representatives, forensic specialists for medicine and odontology, fingerprint and DNA experts, country liaison officers, and representatives of Kenyon International Emergency Services (James 2005). The operation was later, in January 2006, relocated to Bangkok. The identification operation required the cooperation of the RTG, Royal Thai Police, Interpol, foreign governments and individual agencies and organizations. The process of the identification operation performed in Thailand and in Finland is illustrated in Figure 4.

Figure 4. Schematic outline of the identification operation in Thailand and Finland



8.2.4. Finnish DVI team

On 28 December 2004, the Government of Thailand made an official request to Finland for assistance in the identification operation. The National Bureau of Investigation (NBI 2006) reports that the next day two members of the Finnish DVI team left for Thailand to join a Nordic expert group. They were followed on 30 and 31 December by 18 persons of different specialities to search for, identify, and repatriate victims. The team consisted of experts in rescue operations, police work, forensic medicine and odontology, consular affairs, pastoral care, and funeral services. During the most intensive phase of the identification operation, more than 40, even 55, Finnish experts worked in Thailand including two forensic pathologists and autopsy technicians, and a maximum of five forensic odontologists and one dental assistant. Medical and dental experts were needed in the identification center as well as on the body examination lines. The total number of Finnish experts in Thailand in 2005 was 115; of them, a total of 12 were odontologists.

8.2.5. Ante-mortem data

It has been claimed that in the beginning of the operation no regulations existed as to in what form the AM data should be for the identification procedure. It was necessary to choose one common form, because variations in practice existed not only among the 37 countries (Interpol [4]) involved, but also within countries. Concerning dental recordings, both manual and computer-based methods exist, and variations between registration symbols. In some computer programs, the symbols are based on colors. For written information, the language should be the same.

The contract concerning the TTVI operation between the RTG and Interpol included an agreement to use Interpol DVI Guidelines in the identification procedures. Interpol signed an agreement with the Danish software company Plass Data to use the victim identification software DVI System International (Interpol 2005 [5], Andersen 2005).

Some countries, for example Finland, Sweden, and Norway, sent the AM records and radiographs in electric form via the protected police network to the Thai Tsunami Victim Identification - Information Management Centre (TTVI-IMC) in Phuket.

Most DVI teams brought their files as paper forms and original radiographs. In the AM section of the Information Management Centre, the DVI members in the police, in forensic medicine, and in odontology then fed the data for their own missing persons into the DVI System International program (Blau et al 2006).

8.2.6. Post-mortem examination

Site 1

Within the first days after the catastrophe, about 500 bodies were identified visually by their families and relatives and released by the local authorities (Sribanditmongkol et al 2005).

The post mortem (PM) examination began in temporary morgues established mostly in Buddhist temples at accident areas in Krabi, Phuket, and Phang Nga. The day after the tsunami, Thai specialists of different professions started to report for the identification operation. The absence of a centralized command obliged them to form forensic teams independently. They recorded external characteristics and personal belongings and photographed victims. Thai police officers took fingerprints from approximately 600 bodies before the TTVI operation (Sribanditmongkol et al 2005).

On 31 December, Norwegian and Danish DVI teams started their work in Wat Bang Muang or "Site 1b" in Takua Pa district, in Phang Nga province, where most of the deaths occurred. The inadequate facilities like lack of electricity and water made the examination difficult. They decided to use Interpol forms and write findings in English as clear text (Solheim 2005).

On the fifth day after the disaster, volunteer Thai dentists were deployed through the influence of the Thai Dentist Council. A total of 550 dentists from Thailand participated in the operation, most of them without any forensic experience (Sribanditmongkol et al 2005). They helped the Nordic team for instance with digital radiographs. In the early stages of the operation, before decomposition had proceeded, buccal mucosa, hair, and muscle tissue were collected for DNA samples. In decayed bodies, teeth, ribs, and part of a femur were collected.

On 3 January, the operation moved to "Site 1a" Wat Yan Yao in Takua Pa, north of Phuket, under the leadership of Australian DVI officers. According to Standard Operating Procedures (SOP) for a dental examination, findings were to be filled in on Interpol forms as text and with symbols. Teeth and jaws were Polaroid-photographed from the masticatory-surface direction, in occlusion from the left, the right, and anterior. Bite wing radiographs were taken and other pictures at the discretion of the dentists. Two teeth were extracted for DNA samples. At the beginning of the operation, the recommendation was to extract intact posterior teeth. Later, the practice was changed to anterior teeth or canines (James 2005). No exact regulations existed for the numbering of bodies, but the telephone country code of the examination team was added.

Site 2

In about two weeks after the establishment of the TTVI operation, 29th January, a new Thailand Tsunami Identification Centre (Mai Khao Cemetery at Wat Tha Cha Chai) opened in Phuket Province. This, called "Site 2", included a removable field hospital built by the Norwegian company Normeca AS and financed by the government of Norway. In three halls 40 meters long and six meters wide it was possible to maintain six lines for PM examinations. The workplace was equipped with air conditioning, running water, a sewer system and telecommunications. In the area were more than 100 refrigeration containers storing nearly 4 000 victims removed from temporary morgues, which were closed by 15 March, 2005. All bodies were stored at -18°C to keep them in an unaltered condition for PM examination and possible future DNA sample collection, as well as for repatriation procedures.

The first step of the PM investigation was to bring the dead body from its container and lay it on an examination table on wheels. At this stage, the victim could represent any nationality. However, the intention of the Thai authority was to examine their own victims separately from foreign victims.
The teams on the body examination lines were either national groups or combinations of international experts. The Finnish team included members of all specialties: autopsy technicians, forensic odontologists and forensic pathologists, as well as police experts for fingerprints, photographs, and documentation of personal belongings. The teamwork appeared to be efficient due to familiarity with members, language, and manner of proceeding.
Two experts from the Estonian police participated in the examination work as members of the Finnish DVI team.

As the first stage of the examination, the police experts took specimens for fingerprint analysis. With help of a boiling-water method (Interpol [2]) that enhanced the papillary lines appear visible, it was possible to get fingerprints also from badly decomposed bodies.

Police investigators then checked and documented the clothes and belongings of the deceased. From the clothes they noted the size marks and the language used on the labels. Names and dates could be found in some jewelry and documents. In every phase of the investigation, a team member from the police photographed significant objects. The forensic pathologist and the assistant then cleaned the body with a rubber scraper. In the external examination, the characteristic features of the body were observed: scars, tattoos, and conditions congenital or resulting from injuries or medical operations. The sex of the victim was also determined.

The internal examination was performed to find the nature of any previous surgery, and possible pregnancy. Samples of ribs and femur were taken for the DNA research. After the examination, the Finnish forensic autopsy technicians sutured the incision wounds.

At the beginning of the dental examination, the technician made an incision below the mandible in order to remove the soft tissues and uncover the dental arches. The mandible was then removed in its entirety, which was an easy procedure due to the decay process. Some teams seemed to have sawed the mandible vertically in the retromolar area, sometimes even damaging the roots of molars. Some teams resected also the maxilla. In some cases, the jaws were lost, leading to difficulties in identification.

The forensic dental teams comprised a dentist who performed the clinical examination and an assisting dentist or dental nurse who registered the findings using the pink Interpol PM forms F1 and F2, and codes of the DVI System International.

As in a normal dental examination, the basic instruments were the probe and mirror. Tweezers were useful to pick up or search for loosened teeth. Due to the decomposition of the periodontal tissues, single-rooted teeth easily loosened and could be found in the throat of the deceased or in the body bag. In default of a spotlight, a battery-operated head lamp proved useful. A fiber light was helpful not only in lighting but also in distinguishing tooth-colored fillings. The accuracy of the observation was also improved by loupes fixed on glasses.

At the next stage, the teeth were photographed digitally from five projections: frontal, two lateral, and two occlusal. The dentist then estimated the need for radiographs. Bite wing pictures were taken as a rule. Radiographs were also taken of otherwise informative teeth, like those with root canal fillings. Radiographs were required for the age assessment of children, usually from the dentition of the left side of the mandible for the age assessment method of Demirjian et al (1973), and from the wisdom teeth of adolescents (Mincer et al 1993). Age assessment based on the eruption of deciduous and permanent teeth was possible for young children (Nyström et al 2000 and 2001), if oral soft tissues were not destroyed by decomposition.

After the pictures were taken, two teeth, most often mandibular canines, or some other intact teeth, preferably molars, were extracted for DNA samples. Deciduous teeth were not usually taken. Later, instead of teeth, the sample for DNA was collected only from the femur.

Each victim received a registration number that was marked on the body itself, on the body bag, and on the completed forms. After the investigation, the victim was returned in a container until the result of the identification.

To complete the requirements of good practice, a forensic odontologist acted as quality controller who accepted the forms, photographs, and radiographs. These were then enclosed within a plastic folder and heat-sealed. Each of the laminated sheets was disinfected before being sent to the Thai Tsunami Victim Identification Information Management Centre, where the PM data were fed into the computer database for the identification process.

At the most active phase, as many as 120 PM body examinations were performed per day at Site 2 (Interpol 2010 [4]).

8.2.7. Identification

Thai Tsunami Victim Identification – Information Management Centre (TTVI-IMC)

The purpose of the TTVI operation was to identify victims and release the identified deceased for repatriation to their families in accordance with Thai law, Interpol DVI Guidelines, and TTVI Protocols.

The headquarters of the operation, the TTVI-IMC, was located in the office building of the Telecommunications Organization Thailand Company in Phuket. According to Interpol, the center had developed by then the largest for a natural disaster identification operation. The task was to collect all AM information received from the home countries of the missing persons and PM information obtained from examination of the dead bodies for comparison and identification.

On 16 December 2005, the IMC relocated to a permanent facility staffed by Interpol, Thai authorities, and international DVI teams, within the Royal Thai Police headquarters in Bangkok.

Principles of the procedure

The principle for the investigators was to examine victims and perform the comparison impartially and regardless of nationality.

Collection of data

At the beginning of the operation, the main task was to set AM information into the computer program. The AM data was delivered to Thailand either on paper or in electronic form. To avoid mistakes and misinterpretations it was reasonable to have the information programmed by two experts from the country concerned. Interpol DVI forms were used for both AM and PM data.
The PM data received from the morgue teams, written on forms following instructions of the TTVI-IMC and Interpol, were fed into the identification software DVI System International by international team members.

AM-PM comparison

In the reconciliation section, the first step of the comparison was performed by the computer program automatically. To avoid incorrect exclusions arising from errors and defects in the AM information, the criteria were kept quite loose. In dental identification, the suggested hits were then examined manually by forensic odontologists, who classified the findings as *established*, *probable*, *possible, insufficient evidence*, or *excluded*. The conclusion was drawn from examination of radiographs, photographs, and forms, sometimes also of study models. The AM and PM forms could include data open to various interpretations impossible for the computer to solve. For example, the same information could have been registered with different codes, or the width of a filling interpreted as wider or smaller. The *established* cases were confirmed by the reconciliation team leader and a Thai dentist and then, if agreed, submitted with all available supporting evidence to the Identification Board. The IMC Commander authorized the identifications as part of the final quality control process before they were presented to the Identification Board.
In cases of *probable, possible*, and *insufficient evidence,* the identification procedure was continued with the help of additional clinical, radiographic or photographic dental examination. In parallel, other identification methods such as DNA or fingerprints were processed.

Identification Board

The identity of victim was established mainly by dental evidence, DNA, or fingerprints. In many cases, the conclusion resulted from a combination of these supported by physical characteristics and personal belongings. The Board, which consisted of specialists from all areas of forensic and investigative expertise, met regularly to weigh and approve victim identifications made through the DVI process. The identification document was signed by a Thai medical doctor and a DVI commander or a delegate from the international DVI team.

Information concerning methods applied for the identification in Thailand has been promulgated in the Interpol forms *Comparison report*, and *Victim identification report* (part *Certificate of identification*). The identification method used in each case has also been reported in the written statements of the Finnish forensic pathologist.

Release

After the approval of the Identification board, Thai authorities accepted the identification and issued the official death certificate for the release and repatriation. Bodies being held in refrigerated containers at Mai Khao Cemetery (site 2) were, in the beginning of 2006, transferred to the Thai Tsunami Repatriation Centre at Bang Maruan (site 1c) where examination and release procedures were continued. To be sure that the correct body was released, a forensic dentist in charge performed a verification comparing the dentition of the body to PM records.

Repatriation

Most countries had made a contract with the international burial service company Kenyon for the repatriation operations, but some governments, like those of Finland and Sweden, took charge of this through authorities of their own. The repatriation team, consisting of police officers, a dentist, and a burial expert, collected the identified victims from the cemetery and transported them to a service area at Phuket airport. The Finnish and Swedish teams had tents there to prepare the deceased for their last journey home in coffins. At this stage the Finnish experts once more examined the victims to confirm their identity. The bodies were measured, external special marks and the teeth were examined and compared to the AM data. Lastly, the pastor of the DVI team held a prayers for the victims before their transport to the airport.

8.3. Operations in Finland

8.3.1. Events

According to the investigation report of the Major Accident Investigation Committee, the Finnish News Agency (STT) was the first in Finland to report on the Indonesian earthquake at 4:35 a.m. (Finnish local time), one and a half hours after it occurred. The crew of an Air Finland plane on their way to Phuket reported to the traffic control in Finland at 5:15 a.m. about a surge hit on Phuket Island.

The officer on duty of the Ministry for Foreign Affairs received a message at around 6:15 a.m. concerning a disaster occurring in Thailand, and about 7:30 a.m. tsunami waves hit Sri Lanka.
At 6:47, Finnair was informed that Phuket airport was closed due to surging water on the runway.
The Prime Minister and the Minister for Foreign Affairs got the first information from their assistants as phone messages. Other members of the government and the most important authorities were informed before afternoon on 26 December (Major Accident Investigation Committee 2005).

8.3.2. Management of the operation

On the order of the Prime Minister, the leadership of the operation was assigned to the Government Chiefs of Readiness. The first meeting was on 27 December in the presence of representatives of Ministries, the Finnish Red Cross and travel bureaus. On the basis of their reports, the committee decided about leadership, information, and evacuation. The latter should happen as soon as possible at public expense. On 31 December, the committee decided that the evacuation should be performed until 2 January. (Major Accident Investigation Committee 2005).

The Government appointed an Investigative Committee to examine the circumstances of the disaster, and the operations of the authority and the rescue and identification teams based on Accident Investigation act (Laki onnettomuuksien tutkinnasta 373/1985), sections 1 and 3 concerning accident investigation in mass disasters.

8.3.3. DVI team

On 26 December about 9 a.m. the officer on duty of the Ministry of the Interior's Department for Rescue Services received a message as to the tsunami disaster that occurred in Thailand.
The National Bureau of Investigation (NBI) started on the same day the plan of action, and communicated with Nordic DVI teams. On 28 December, the Government of Thailand made an official request to Finland for assistance in the identification operation. From 29 December, representatives of the NBI participated in the meetings of the Committee of Readiness Managers. By order of the Ministry of the Interior, a specific Asia team was established within the NBI. The task after the evacuation was the collection of lifetime data about missing persons, and the examination, identification, and repatriation of victims. On 29 December, two NBI experts of the DVI team left for Thailand, and in the next days, 18 members with different expertise followed them. Altogether 115 experts participated in the identification operation in Thailand during 2005. In Finland approximately 200 experts served under the NBI in tasks connected to the catastrophe (NBI).

8.3.4. Legal aspects

The first task of the NBI was to learn the number and names of the supposed victims. The list of missing persons was published on 30 December by the NBI. Finnish law has no exhaustive regulations to forbid or allow the publication of a list of missing persons. The Constitution of Finland includes directions for the protection of personal data. Nowadays, most industrialized countries share common values including respect for human rights and personal privacy. Within the European Union (EU), the legislation focuses on the same goals in directives. Each member state is expected to introduce the principles of the EU directives into their corresponding national legislation. As an example, directive 95/46/EC on personal data and free exchange of information is incorporated into the Personal Data Act (Henkilötietolaki 523/1999) in Finland.

To complete the Personal Data Act, additional decrees have been given. Significantly, any information in relation to individual's health care and medical treatment is strictly protected. In Finland, national legislation contains among other things the Act on Health Care Professionals (Laki terveydenhoidon ammattihenkilöistä 559/1994). Section 24 obliges the National Authority for Medicolegal Affairs (TEO) to keep a central register of health care professionals (from 2009 onward the National Supervisory Authority for Welfare and Health [Valvira]). Section 15 contains obligations related to professional ethics, and section 17 secrecy obligations, which shall continue after the professional activity has ended. The Act on the Status and Rights of Patients (Laki potilaan asemasta ja oikeuksista 785/1992) prescribes in section 13 that health care professionals or other persons working in health care or carrying out its tasks shall not give information contained in patient documents to outsiders without the written consent of the patient.

In special situations like accidents, however, authorities are to receive access to protected individual data if needed to accomplish their duties for the benefit of the person concerned.

Provisions for access are strictly regulated in the Penal Code (Rikoslaki 39/1889). Chapter 38 includes data and communications offences, and Chapter 40 contains offences in office such as exposure of official secrets. The Act on the Openness of Government Activities (Laki viranomaisen toiminnan julkisuudesta 621/1999) prescribes as the general principle that official documents shall be in the public domain, unless otherwise specifically provided in this or another act.

The Act of the Inquest into the Cause of Death (Laki kuolemansyyn selvittämisestä 459/1973) includes regulations related to forensic examinations and documents. Only the authorities concerned, the court, and the closest relatives are allowed to receive the information. The medico-legal investigation and the identification of tsunami victims required application of these acts.

By consulting the Ombudsman, and based on the Act of Rescue Service (Pelastustoimilaki 561/1999), the legality of the publication was confirmed. The common weal was also taken into consideration. On 30 December 2004, a list with 263 names was published on the web site of NBI. Within a few days the list reached its final form, including 178 names.

8.3.5. Collection and availability of dental ante-mortem data

To collect AM data, the Finnish Dental Association contacted the National Bureau of Investigation immediately after the disaster, offering the use of its protected infrastructure to reach individual practitioners. On 31 December all 4800 dentists and chief dental officers of five major health care centers were provided with the list of missing persons and requested to assist authorities by sending any existing data found in their files. In Finland, the rehabilitation of edentulous people is a duty both of dental practitioners and special dental technicians. The latter were not requested to search their files for AM data.

As members of the Finnish DVI team, three forensic odontologists analyzed the information in patient records and radiographs, storing these data on the Finnish Human Identification (HUID) program. HUID was originally designed in the early 1990's and was applied in the *m/s Estonia* ferry disaster of 1994. Later, the database was converted in Finland into the official tsunami victim identification program, the DVI System International of the Danish Plass Data Company (Plass Data 2003), and sent via the protected network of the police to the TTVI-IMC. The radiographs were scanned or photographed digitally, and added to the documents.

8.3.6. Collection and availability of medical and DNA antemortem data

The collection of the medical AM data required a different approach. Police officers of the NBI Asia group collected AM information by interviewing relatives and searching missing persons' homes and their belongings for fingerprint and DNA samples. The relatives were often able to describe the person's individual physical characteristics, congenital or caused by diseases or treatment. The location where they received treatment could often be identified.

in Finland, the availability of material for providing direct DNA profiles for mass disaster victims is limited, as no national DNA databank or tissue bank exists. This leaves two options for retaining material for direct DNA profiles: personal belongings, and biopsies stored in hospital archives.
Reference samples from the relatives constituted the most valuable information for identification. At the start of the operation, law enforcement officials collected buccal swabs from relatives for reconstruction of DNA profiles for the victims. The DNA reference sample collection and analysis were carried out jointly by the Department of Forensic Medicine of Helsinki University and the Crime Laboratory of the National Bureau of Investigation.

Another request of the NBI was addressed to hospitals where some of the missing persons were known or supposed to have been patients. The purpose of this request was to obtain any medical AM data like patient records and radiographs. Identifiable characteristics resulting from treatment, illness or accident were sought.

Both requests, for medical records and samples for DNA, included a reference to the Act of the Inquest into the Cause of Death (Laki kuolemansyyn selvittämisestä 459/1973) that obliges the hospital to give this information to the police.
The National register of implants was also searched for information. The Finnish National Agency for Medicines has maintained a centralized data base on all orthopedic endoprostheses and dental

implants installed in Finland. From the beginning of November 2009 this task was assigned to the National Institute for Health and Welfare (Terveyden ja hyvinvoinnin laitos 2011).

8.3.7. Repatriation

The evacuation of surviving Finnish nationals occurred between 27 December 2004 and 2 January 2005. In one week, about 3 300 persons were repatriated on 17 evacuation flights ordered by the government, and about 400 persons on regular flights (Major Accident Investigation Committee 2005).

The repatriation of the identified deceased began on 10 January in Finland, the bodies honored by an official ceremony at Helsinki-Vantaa airport. By February 2006, all victims found and identified in Thailand and Sri Lanka had been transported to Finland.

In Finland, in contrast to many other countries, a medico-legal investigation to determine the cause of death was performed on every repatriated victim. Besides this, identification was verified, mainly by DNA, fingerprint, or dental comparison. Finally, the Identification Board confirmed the identity, after which the body was released to the relatives for the funeral.

8.3.8. Investigation of cause and manner of death

Orders concerning the forensic investigation of the repatriated victims were given by authorities on 2 January 2005. Section 7 of the Act of the Inquest into the Cause of Death obliges the authority to perform an examination in accident cases.

Victims found and identified in Thailand, and in one case in Sri Lanka, underwent in Finland a full forensic investigation. This included a complete autopsy with histological and toxicological samples. A computed tomography (CT) and digital radiographs were taken of the whole body. The X-ray machine used in the study was Siemens Multix CPH. The computed tomography was performed in the Surgical Hospital (2009) of Hospital District of Helsinki and Uusimaa (Kirurginen Sairaala, Helsinki). The identity of the victims was ensured by DNA, fingerprints or a forensic odontological examination. The dental identification included besides a clinical examination also panoramic tomograms (Ortopantomograph 6, Palomex Instrumentarium Oy, Finland). The autopsy with DNA and dental examinations took place at the Department of Forensic Medicine of Helsinki University (from 2010 Hjelt Institute).

In the external investigation, recent injuries were detected and documented as well as scars and other indications of old trauma and individual characteristics for purpose of cause-of-death investigation and identification. The internal investigation included besides the complete autopsy also sampling specimens for DNA, and toxicological and histological investigation. Digital radiographs and computed tomography were taken to verify autopsy findings and to detect particularly hard tissue damage caused by trauma, autolysis, and sampling for DNA in Thailand.

The material for the analysis constituted of the radiological material with specialist's statements of the CT study, digital photographs taken by the police during the autopsy, the results of the forensic medical, dental and DNA investigations, and the statement of the identification boards of Thailand and Finland. The forensic medical autopsy records included results of the external and internal body investigations, microscopic and toxicological examinations, the conclusion of the findings, and the death certificate.

The information concerning adults (n=109) and children (n=56) (<18 years) were analyzed separately, because of their different ability to resist external forces and the decay process.
The body of one child victim was cremated in Thailand after the identification. Only ashes were available. Therefore the total number of children examined in Finland was 55 instead of 56.

8.3.9. Verification of the identity

The manner of proceeding included orders to verify the identity of the victims in connection with the autopsy.

The new PM data for the forensic dental examination was collected by clinical and radiographic examinations. In Finland, the conclusion as to dental identification includes four categories. If dental evidence is enough to judge without hesitation the identity, the identification is *established*. The term *probable* means that the dentition contains details that in a small victim group within a closed disaster could be enough for an identification, but in large populations does not guarantee the identity of the person concerned. If the dentition of the dead body or the missing person or either lack both personal properties and contradictions, they may *possibly* be the same person. An *exclusion* occurs when the dentitions prove to be different when compared to each other. Any discrepancy between AM and PM information must be explainable; otherwise no identification is possible. In the absence of either AM or PM data, no comparison can be made.

For any established identification, the result of age assessment, besides other PM findings, has to be in concordance with the AM data. Age was assessed for children and adolescents by dental methods based either on the eruption (Nyström et al 2000, 2001), applied to eight examinations or developmental stage of the crown and roots (Demirjian et al 1973, Mincer et al 1993). The Demirjian method is based on the developmental status of seven permanent mandibular teeth on the left side. It was applied to 33 cases using the dental maturity curves of Finnish children (Chaillet et al 2004, 2005). The A.B.F.O. method (Mincer et al 1993) is based on the development of wisdom teeth, the only teeth still developing in late adolescence. This method was used in seven cases. In adults, age assessment is based on physiological and degenerative changes in the dentition. Because these are individual, results tend to be inaccurate. Age was assessed "visually" by weighing clinical and radiological findings such as number of teeth, attrition, color, root resorption, loss of dental attachment, width of pulp chamber, and materials for tooth restorations.

For the identification, PM samples for DNA analysis came from a femur of each repatriated body in connection with the autopsy.

The forensic pathologists noted any unique physical or medical characteristics such as scars and other kind of marks of old traumas and individual characteristics found during the external body investigation. Then, during the autopsy, physical characteristics and findigs of surgery or other medical treatment were recorded for identification purposes.

Other evidence, such as fingerprints and personal belongings (jewelry, documents, clothes), were also noted. These were collected in collaboration with the NBI.

8.3.10. Identification board

The Identification Board held its sessions in the headquarters of the Asia operation in the building of the National Bureau of Investigation in Tikkurila, Vantaa. The committee consisted of a police officer as the chairman and three members including representatives from the police and from forensic medicine and dentistry. Its task was to confirm identity on the basis of dental evidence, DNA or fingerprints, or combinations of these, supported by or physical characteristics and personal belongings.

RESULTS

The estimated number of victims, missing or dead, of the tsunami disaster was approximately 230 000, of which 160 000 were in Indonesia, 35 000 in Sri Lanka, and 16 000 in India. Of the 5 395 fatalities in Thailand, approximately 2 400 were foreign nationals from 36 different nations (Interpol 2010 [4]).

9. Dental ante-mortem data

9.1. Finland

The dental AM data collecting started on 31 December 2004 in the NBI. The dentists reacted quickly to the request concerning patient files. Within the first week of January 2005, dental information was received from 80% of the 171 individuals on the list who had been in Finland. Additionally, AM records were available for the man who perished in a Finnish hospital soon after the evacuation. Eventually, five of the missing persons remained without any data including three children (1 to 4 years), an elderly (76) nearly toothless man, and a middle-aged man (53) negligent about his dental care. AM dental records of seven missing Finns living in Sweden also were lacking. All useful dental AM data was available and examined for identification within one month after the disaster.

More than 70% of the files included radiographs. These consisted of bite wings, panoramic tomograms, and periapical radiographs. In exceptional cases, lateral skull radiographs and dental models were available.

The dental health of the children proved to be good, with few fillings and carious lesions in deciduous dentitions. The permanent teeth of the young people were also excellent: mostly caries free and often orthodontically straightened. Thus, after the completion of the dental AM data base, it could be expected that dental identification could be established for 20% of the children aged under 18 years. A finding of *probable* existed in 15% of the cases, and *possible* in 60%. AM data were lacking for 5% of the children (Table 2).

Table 2. Prediction of dental identification of Finnish victims based on ante-mortem data

	Number	Established (%)	Probable (%)	Possible (%)	No data (%)
Adults	112	96 (85.7)	6 (5.4)	8 (7.1)	2 (1.8)
Under 18	60	12 (20)	9 (15)	36 (60)	3 (5)
Total	172	108 (62.8)	15 (8.7)	44 (25.6)	5 (2.9)

Adults usually have good files on their dental treatment, and many have restorations enough for an *established* identification. The estimate for those, based on the AM data, was 86%. A *probabl*e finding was expected for 5%, and a *possible* for 7%, while for 2%, no AM data existed. Altogether, 63% of the missing persons living in Finland had AM files good enough for an established identification. For 28%, the groups *possible* and *no data*, dental evidence was insufficient. In 9% of the victims, the *probable* group, dental evidence was sufficient to support the identity determined by other identification methods.

Of the five Finnish nationals who are still missing, one, a woman, has AM files sufficient for dental identification, but for the four missing children, DNA or fingerprints would be the means of identification, had their bodies been found.

9.2. Thailand and other countries

The accumulation of AM data started quickly at the beginning of 2005 and gradually decreased during the DVI process. Some records were still being received in November. Even after that, it was possible to add supplementary information to existing files. As late as in the beginning of 2006 a new notice of a fractured and restored incisor of a Finnish girl was sent to the TTVI-IMC.

According to data updated on 12 December 2005, 3 547 persons were reported missing; of them 1 573 were Thai nationals and 1 693 were Europeans (Petju et al 2007). The final number of AM files recorded in the TTVI database was 3 574 (Interpol 2010 [4]).

To obtain AM data on Thai nationals, their families were asked to collect data from dental clinics to be sent to the TTVI-IMC. The Thai dental Council sent lists of missing persons to practicing dentists with a request to search their files for AM information. Dental records of nearly 100 victims were lost in a dental clinic destroyed by the tsunami. Dental charts were received for 18.1%, and dental radiographs for 0.8% of victims (Petju et al 2007). From the 19 European countries involved, dental charts of 94.4% (n=1 598), and radiographs of 75.5% (n=1 278) were available. In total, of the countries involved, dental records existed for 55.8% (n=1 979) of the 3 547 missing persons. Dental radiographs were available for 38.4% (n=1 361).

Of the 284 Thai dental records available, 21 (7.4%) were successfully usable for dental identification. Registered dental status was lacking in most charts; information on treated teeth existed, but often without details concerning materials or treated surfaces (Petju et al 2007).

10. Medical, physical, and DNA ante-mortem data, Finland

Medical and physical AM data included any information about individual characteristics, congenital or caused by diseases or treatment.

Data of variable quality existed for 117 persons. In 17 cases, the information was insufficient, or the illness or treatment caused no sequela useful for identification purposes. No AM information was available for 61 persons. Seven of them lived in Sweden. In 71 persons including 42 adults and 29 children, physical and medical characteristics were noted in the *Certificate of identification* of the Finnish Victim Identification Board as supporting factors for the identification.

Concerning samples for DNA, archival biopsies were available for 57 victims, and personal items for 26. For five victims, both tissue samples and personal items were recovered. Direct DNA profiles were thus potentially obtainable for altogether 78 of the missing individuals living in Finland. As with the dental data, children were underrepresented in the available samples: only two had tissue samples, and ten had personal items. From personal items proper samples for direct DNA profiles were available for only 11 of the 26 victims. Reference samples from the relatives comprised the most valuable information for the identification. With the start of the operation, the law-enforcement officials collected buccal swabs from 144 relatives for reconstruction of DNA profiles for the victims.

A problem in sampling of reference material for child victims from the relatives was that the most informative reference-sample donors, the parents, were themselves often among those who perished. The 172 missing nationals living in Finland were connected to 75 extended families, of which 42 lost more than one family member. In 32 families, the victims represented two or more generations; one of these was an extended family that lost 12 members belonging to three generations (Palo 2010).

11. Post-mortem data

The Thai Tsunami Victim Identification (TTVI) operation, established by the Royal Thai Government together with Interpol, included an agreement to use Interpol DVI Guidelines in the identification procedures. PM data that was collected before the TTVI operation was often insufficient, and required supplementary examinations. The manner of proceeding developed within the first weeks, thus resulting in new recommendations, orders, and additional examinations.

11.1. Thailand

Before the TTVI operation, Thai forensic teams examined more than 3600 victims. Of them, 111 bodies were identified based on dental records, the rest mainly on external properties (Sribanditmongkol et al 2005).

During the most active period of half a year after the disaster, 520 Thai dentists (Petju et al 2007) and about 200 dentists from more than 20 countries (James 2005) had participated in the dental forensic investigation.

The international teams were restricted to examining only the deceased assumed to be other than Thai nationals.

Of the approximately 3750 bodies in the TTVI database examined during 2005, 97.4% were in a condition good enough for a dental examination; the rest consisted of body parts or bodies without the head (Petju et al 2007).

According to Interpol (2010 [4]), the final number of victims registered in the DVI System International PM database of TTVI-IMC was 3681.

11.2. Finland

Of the 179 Finnish nationals killed by the tsunami, 172 were identified in Thailand, and 165 repatriated to Finland including a woman who died in Sri Lanka, and the severely injured man who later died in a hospital. Seven Finnish victims were returned to Sweden and one to Greece where they lived, and one was buried in Thailand. Five persons, one adult and four children are still missing. The last two victims were repatriated to Finland in January 2006.

In comparison, of the 543 Swedish victims, 526 were identified by 12 December 2005 (Den svenska identifieringskommissionen 2006).

In contrast to other countries, in Finland all underwent a complete forensic post-mortem investigation with autopsy, DNA analysis, dental identification, and a radiological study by digital radiographs and computed tomography. Some exceptional cases were due to injuries, or to the manner of handling of bodies. Of child victims, one was cremated, another lacked the head, and in one case the mandible had been resected and lost. Of adults, the lower jaw was missing for one, and both jaws for two; these jaws were removed and lost during the PM examination in Thailand. For sampling of fingerprints, the hands of 11 Finnish adult and 3 child victims were removed in Thailand, and in one case, the hands were lost.

In Thailand, two intact teeth, most often permanent lower canines, were removed for DNA analysis. In 102 adult cases in which both jaws were present, the number of teeth missing post-mortem ranged from one to nine, on average 2.7. The number of Finnish adult victims with teeth extracted for DNA was estimated as 94. In children, this estimated number was 37. This action reduced the reliability of the AM/PM comparison, and also limited the applicability of the exact and commonly used dental age assessment method of Demirjian et al (1973) to 33 cases. The decay of gingival tissues reduced the age-assessment methods based on dental eruption to eight cases.

12. Identification

Sribanditmongkol et al (2005) report that in Thailand, during the first days after the disaster, approximately 500 victims were identified visually by families and released by local authorities. Thai forensic teams examined more than 3 600 cases and released approximately 1 100 of them. During the first few days when bodies were still quite intact, the identification was confirmed mainly by external appearance and physical characteristics.

The difference between the official number of missing persons in Thailand (n=5 395) and the final number of PM files (n=3 681) in the database of the Thai Tsunami Victim Identification-Information Management Centre (TTVI-IMC) shows that 1 714 bodies were released before the TTVI operation. Most of these were identified by visual and physical evidence (Interpol 2010 [4]). After the establishment of the TTVI operation, the identification was based mainly on DNA, fingerprints, and dental evidence. In some cases, medical condition or physical characteristics of the body or a combination of evidence has been the method of choice. Personal belongings of the victim have often been valuable in supporting the identification.

By 12 December 2005, AM files of 3 547 persons and PM files of 3 750 victims were incorporated into the DVI System International database of the TTVI-IMC (Petju et al 2007). The final numbers, according to Interpol (2010 [4]) in February 2006, were 3 574 AM files and 3 681 PM files. The decrease in PM numbers results from elimination of duplicate files.

12.1. Thailand

Under Thai law, a forensic investigation is required in sudden accidental death. Before the tsunami, forensic dentistry in Thailand had played only a minor role in forensic sciences, without national standards and guidelines. One year after the disaster, 2% of Thai victims had been identified by dental methods. After the establishment of the TTVI operation, the dominant identification method for Thai victims was based on fingerprints (59.2% by the end of 2005) (Petju et al 2007).

In the beginning of the TTVI operation, in March 2005, when altogether 951 victims were identified, the dental method proved to be the most successful: it was applied in 837 (88%) of the cases; 57 bodies were identified by fingerprints (Schuller-Götzburg 2007). Later, the importance of DNA and fingerprint methods increased significantly.

According to the report of Interpol (Dec 2005 [6]), during 2005, under the TTVI operation, more than 2 000 experts from 31 countries had participated in the identification process of nearly 3 000 victims of the 3 750 recorded by the TTVI-IMC.

Petju et al (2007) report that of the identifications of the 2 894 victims, performed by 12 December 2005, 46.2% were based on dental evidence, 18.6% on DNA, 34.4% on fingerprints, and 0.8% on physical characteristics.

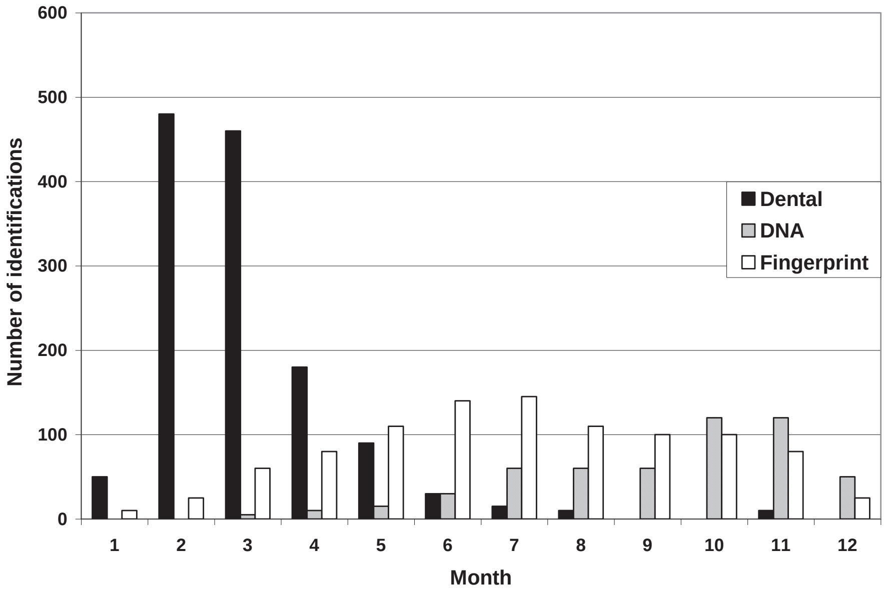
According to the Interpol Tsunami Evaluation Working Group (2010) which has summarized the final results of the identification operation, a significant number of identifications, 1 248 (43%), were based on comparative dental analysis alone. Of the identification results, 880 (30%) were combinations of different methods. DNA and fingerprints were often connected to physical evidence.

According to the analysis by Petju et al (2007) based on the TTVI-IMC database, updated in December 2005, dental identification was applied mainly from January to May 2005 (Figure 5). The dental method was applied in the first place to adult European victims (76% of identifications). More than 75% of the victims from North America (n=34), Oceania (n=15), and Africa (n=4) were also identified by dental evidence. The significance of the fingerprint method increased considerably, being the principal method from May to October. The great number of victims identified by fingerprints comprises mostly Thai (59% of identifications) and other Asian nationals

(71%). For successful fingerprint identification, Thailand has an official register of fingerprints for use on identity cards (Schuller-Götzburg 2007).

After difficulties at the start, the applicability of DNA comparison increased, becoming the most useful method after October 2005 especially for child victims as well as for badly damaged and decayed bodies.

Figure 5. Identification methods applied in Thailand during the 12 months after the tsunami
(Based on database of Petju / TTVI-IMC 2007)



The majority of the Finnish victims were found and examined in Thailand during January and February 2005. The period between PM examination and identification varied greatly, from over a week to one year, depending on the quality of the evidence for the identification.

According to the data collected on the 107 Finnish adult victims, a positive identification result was achieved in Thailand 94 times by dental comparison, once by DNA, and eight times by the fingerprint method (Table 3). Physical characteristics were used in five cases in addition to other methods, in one case supported by personal properties. In three cases, no information was available concerning the identification method.

For the identification of Finnish children in Thailand, DNA was used in 16 cases, once in addition to dental evidence, and three times with fingerprints. Dental methods were used in 12 cases; besides those above, three times with fingerprints. Fingerprints were used in a total of 32 cases. Physical characteristcs were used once alone, and three times with fingerprints. Two cases lacked any information.

Of the Finnish nationals who died in the disaster, 97% have been recovered and identified.

Of the five Finnish nationals that still are missing, a female adult has AM files sufficient for dental identification. Dental evidence on three missing child victims reaches only the identification category *possible*. One more child, one year of age, lacks dental AM information.

Table 3. Identification methods in Thailand and Finland for the Finnish Tsunami victims.

	Thailand		Finland	
	Adults n=107[1]	Children n=56	Adults n=109	Children n=55[2]
Method				
Dental	92	8	95	6
DNA	-	12	6	22
Fingerprints	6	23	4	18
Physical characteristics	1	1	1	-
Dental + DNA	-	1	-	3
Dental + fingerprints	-	3	3	5
DNA + fingerprints	-	3	-	1
Dental + physical	2	-	-	-
DNA + physical	1	-	-	-
Fingerprints + physical	2	3	-	-
Unknown	3	2	-	-

[1]One perished in Sri Lanka and one in Finland
[2]One cremated

As part of the ongoing identification and repatriation process, bodies being held at Mai Khao Cemetery (site 2) were transferred to the Thai Tsunami Repatriation Centre at Bang Maruan (site 1c), where the final examination and release procedures will be continued. According to the Interpol Tsunami Evaluation Working Group (Interpol 2010 [4])," The multi-national team was to remain in Thailand for a total of 14 months. At the time of their departure on the 28th February 2006, 508 victims remained unidentified."

Beginning on the first of December 2006, 513 bodies of Tsunami victims that had gone unclaimed or unidentified for nearly two years after the catastrophe were buried in temporary graves. The bodies included 103 victims who were identified, but whose families had not yet collected the remains. They included 72 Myanmar nationals, 28 Thais, one Filipino, one Turk, and one Nepalese. The other 410 bodies were unidentified. DNA samples have been collected from all the bodies, so if any new evidence emerges, it is possible to exhume the bodies to complete the identification process. Thai officials decided to bury the bodies because the containers were not designed for such prolonged use (Thai Visa Forum 2006).

According to this information, the number of identifications by the first of December 2006 was 3 271 or 89% of the 3681 victims in the TTVI-IMC database.

12.2. Finland

12.2.1. Repatriation of victims

Repatriation of the Finnish victims began on 10 January, when a 13-year-old girl who had died in a Thai hospital was returned to Finland. The first victim, however, examined at the Department of Forensic Medicine, University of Helsinki, was the seriously injured man who died soon after his evacuation from Thailand. The autopsy was performed on the third of January 2005. The only Finnish national who died in Sri Lanka was identified as early as on 12 January and examined in Finland two weeks later.

By February 2006, 163 of the 172 victims found and identified in Thailand were removed on 46 flights to Finland.

By the end of March 2005, about half the Finnish victims, 88, had been repatriated and examined; of these, seven were children. Of Finnish adult victims, about 90% were found and returned during four months after the disaster (Figure 6). Of child victims, approximately 70% were returned within the period from April to August, 2005. The last two victims found, a nine-year-old girl and a 13-year-old boy, were examined in Finland on the first of February 2006.

The repatriation took place on average two weeks after the identity was established in Thailand. The shortest period was seven days.

Altogether, 165 Finnish victims were examined at the Department of Forensic Medicine in Helsinki. Of them, 109 were adults and 56 were children under 18 years of age. The age distribution is presented in Table 4.

One child victim was cremated as consequence of an incorrect identification, later corrected, performed in Thailand. The PM material constituted of ash and 26 small hard tissue particles. For this four-year-old boy, AM files were lacking, as well. According to the *Police comparison report* of the Thai Tsunami Victim Identification Centre, the remains of a disaster victim, labeled PM61-1-00323, were declared as identified on 20 May 2005 as a British child, and the corpse was released on 26 May. Re-examinations, however, by DNA, supported by physical evidence (sex, age, height, build, race and hair of the head) showed a correlation between a Finnish child and these PM files. The DNA and physical evidence of the missing British child matched the PM files of another victim. The *Victim Identification Report* on the Finnish victim was signed on 25 November 2005.

Figure 6. The number of Finnish adult and child victims repatriated during the 14 months after the 2004 tsunami catastrophe

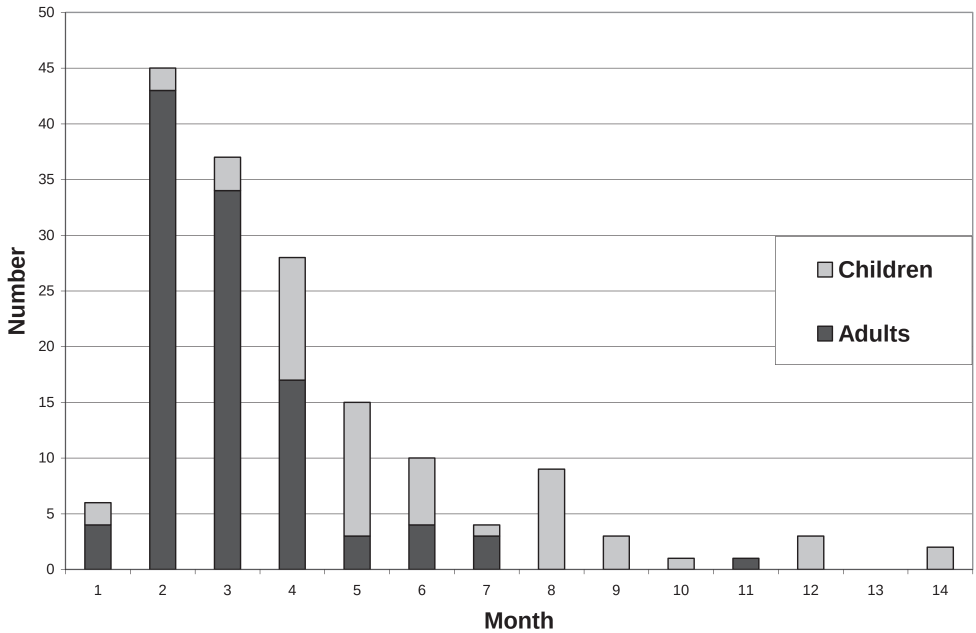


Table 4. Age distribution of Finnish victims examined in Finland

Age in years	Female	Male	Total
0-9	18	12	30
10-19	13	16	29
20-29	4	1	5
30-39	17	12	29
40-49	19	24	43
50-59	4	12	16
60-69	5	3	8
70-79	2	3	5
Total	82	83	165

12.2.2. Identification methods and results

In Finland, according to the victim identification report of the Finnish Identification Board, 95 of the 109 adult victims were identified by dental methods, 6 by DNA, and 4 by fingerprints. In one case, as the victim was toothless, identification was based on physical chracteristics, with evidence for his identification constituting mainly conditions of recently performed tooth extractions, and his age. This identity was also verified by DNA. Additionally, in three cases the identification was based both on dental methods and fingerprints.

According to the *Certificate of identification* of the Finnish Victim Identification Board, in 50 cases, dental information, age, physical or medical characteristics, or personal property have supported the identification. In 100 cases, the chosen method for the identification was the same in Thailand and in Finland.

In the Finnish examination of child victims for verification of the identification, DNA was the method of choice in 26 cases, used there 3 times together with dental methods, and once with fingerprints; 14 victims were identified by dental methods, 5 of them together with fingerprints. Fingerprints were used in a total of 24 cases (Table 3).

In 45 child cases, the identification method was the same in Thailand and in Finland. In 40 children, dental information including age assessment, physical characteristics, or personal property have supported the identification. Of these, dental evidence or age assessment by dental methods succeeded in 33 cases.

In 71 cases, 42 adults and 29 children, medical or physical characteristics have been considered sufficiently individual to support the identification established by primary methods. As exceptional supporting findings, the medical data included two cases in which one toe was amputated, and one case with an aorto-ilical Y-prosthesis; all were identified by dental evidence. Once, DNA and prostheses in both knees constituted the basis for identification.

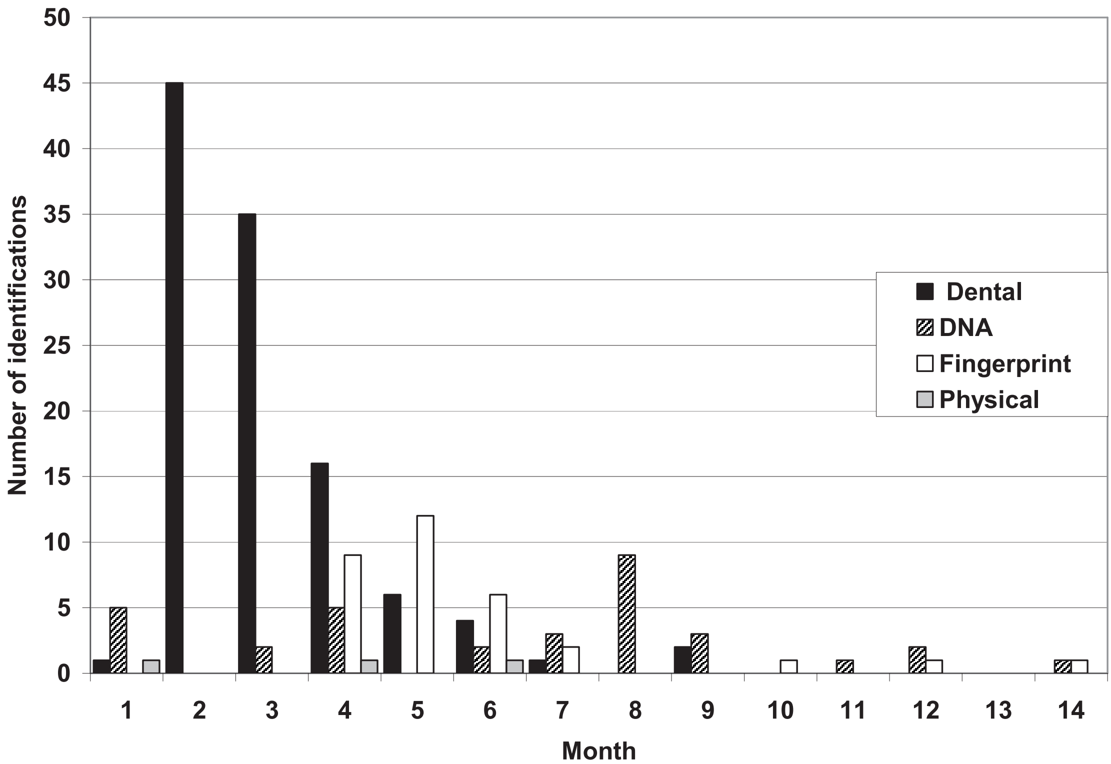
Overall, an established identification result in Finland was achieved in 32 cases by DNA, in 31 by fingerprints, and in 112 by dental comparison. In 12 cases, two identification methods were applied.

Despite the identification methods used in Thailand or in Finland, the identity of every Finnish victim was additionally verified by DNA, analyzed in samples taken from the femur.
Despite the differing identification methods applied in Thailand and Finland, no discrepances existed concerning identity.

Of the Finnish nationals, the one repatriated to Greece and the one buried in Thailand had their identity verified by a Finnish identification board established in Phuket, Thailand. The identification of the first one was based on dental evidence and of the second, on fingerprints.

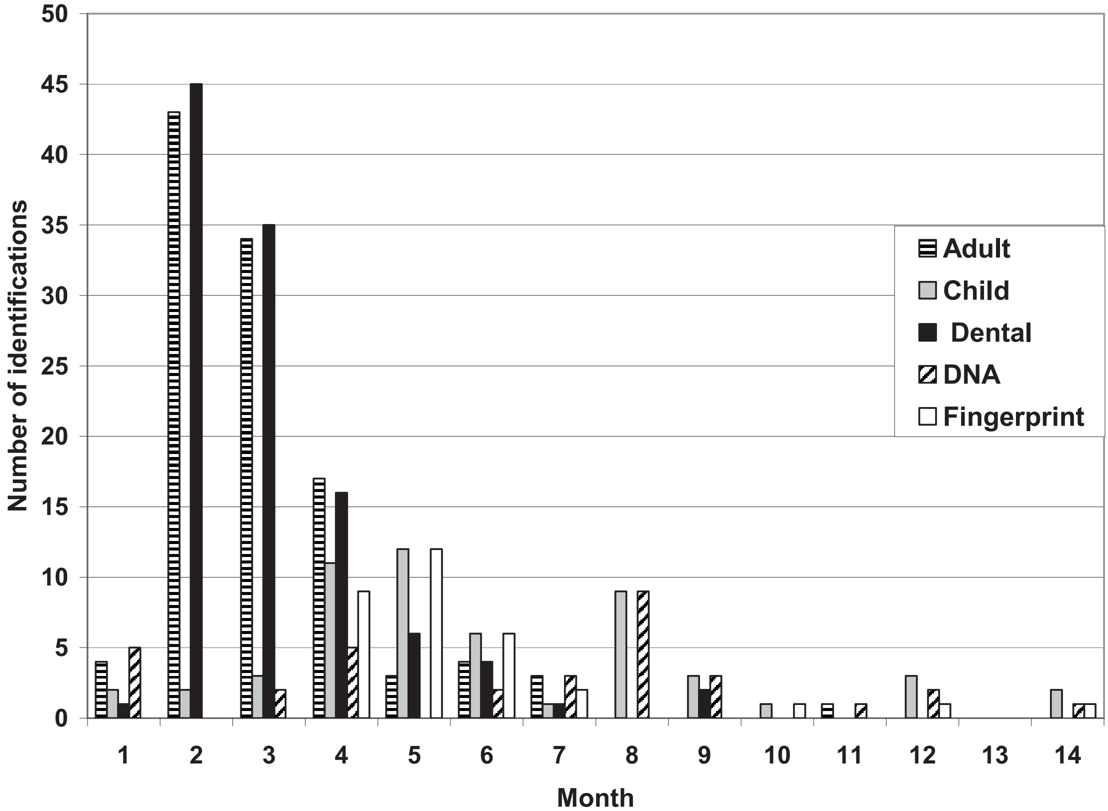
The applicability of the identification methods varied as the operation was progressing (Figure 7). In the beginning, dental comparison proved to be the method most frequently used. Later, fingerprint and DNA methods were more applicable.

Figure 7. Methods applied in Finland to the verification of the identification during 14 months after the tsunami disaster.



As illustrated in Figure 8, dental identification was applied in Finland to the majority of adult victims. If AM information was available, the dental comparison could be performed quickly. Concerning child cases, the dental evidence often was insufficient to establish identification. In these cases, comparative DNA and fingerprint analysis were effective.

Figure 8. Identification methods applied to 165 repatriated Finnish adult and child victims during 14 months after the disaster (combining Figures 6 and 7)



In Finland, *probable* was the identification result in 21cases: 19 children and 2 adults. The category *possible* applied to 25 cases, of which 5 were adults. Of these adults, one lacked the lower jaw, and the upper one was toothless; two were totally and one nearly toothless. One with an intact dentition was 18 years and one month old (Table 5). Of the victims repatriated, seven had no data for dental identification. Of adults, two lacked any AM data and two lacked both jaws, which were removed and lost in PM examination in Thailand. Of one child victim, the head was missing, one was cremated, and one lacked AM files.

Table 5. Dental identification of Finnish victims.

	Number	Established (%)	Probable (%)	Possible (%)	No data (%)
Adults	109	98 (89.9)	2 (1.8)	5 (4.6)	4 (3.7)
Under 18	56	14 (25)	19 (33.9)	20 (35.7)	3 (5.4)
Total	165	112 (67.9)	21 (12.7)	25 (15.2)	7 (4.2)

PM data have come from dental examinations in Finland.

12.2.4. Age assessment

In adults, age assessment is based on physiological and degenerative changes in the dentition. Because these are individual, results tend to be inaccurate. The degree of the accuracy of the "visual" method has been to within about 10 years.

For verification of the identification of Finnish tsunami victims, age assessment of the children was by dental methods based either on the clinical eruption or development of teeth. The applicability of each dental method is dependent on the developmental stage of the child concerned. For very young children, the most suitable method may be counting the erupted deciduous teeth to compare with Finnish reference tables. In many cases, however, this method could not be applied due to the decomposition of soft tissues. This method of Nyström (2000, 2001), based on eruption of deciduous or permanent teeth, was the chosen alternative for young children in eight cases. The difference, over or under the chronological age, was on average 5.6 months (Varkkola et al 2011).

The Demirjian method (1973), based on the developmental status of seven permanent mandibular teeth, was applied to 33 cases, using the dental maturity curves of Finnish children (Chaillet et al 2004, 2005), resulting in an average difference of 5.2 months. Problems in nine cases were caused by missing teeth due to the decomposition of the tooth-surrounding soft tissues, or to extractions for DNA samples in Thailand.

The third method, A.B.F.O. (Mincer et al 1993), based on the development of wisdom teeth, was applied to seven examinations. The difference was on average 12.6 months between chronological and estimated age.

The age of the 56 children under 18 ranged from 2 to 17 years (Table 6).

Table 6. Age distribution of the Finnish child victims repatriated and examined in Finland

Age	Female	Male	Total
0 - 2.9	0	2	2
3 - 5.9	10	4	14
6 - 8.9	5	4	9
9 - 11.9	4	5	9
12 - 14.9	6	9	15
15 - 17.9	4	3	7
Total	29	27	56

Later, a comparative examination (Varkkola et al 2011) was made to discover the reliability of various skeletal and dental age assessment methods based on information on child victims aged less than 16 (n=52).

The skeletal methods in the study were radiological, based on the developmental status of bones of the hand and wrist (Dreizen et al 1957, Loder et al 1993, Mora et al 2001, Murata 1997, Ontell et al 1996, van Rijn et al 2001, Wenzel et al 1982).

Age assessment based on the Greulich and Pyle method (1959) could be performed in 47 cases, including 23 girls and 24 boys. On average, the difference from chronological age was 9.7 months.
Injuries of fingers in several victims limited the assessment by RUS (Radius, Ulna and Short bones by Tanner, Whitehouse et al 1983) and 20-bones methods (Tanner, Whitehouse et al 1983) to 35 cases. The 20-bones method - a combination of carpal and RUS methods - differed by 10.3 months from chronological age.

13. Cause-of-death investigation in Finland

The medico-legal autopsies were performed in Finland during the period from 3 January 2005 to 1 February 2006. All the cadavers showed extensive PM putrefaction, and showed signs of the previous PM investigations in Thailand (e.g. autopsy, manipulation of jaws, DNA sampling from teeth, ribs and femoral bones).

Injuries of variable degree in different parts of the body proved to be common findings. Only 36 victims had escaped detectable injuries, 32 adults and 4 children. Peri/ante mortem trauma had occurred in 41 adult and 8 child victims. Of the cases remaining, 80 were classified as PM or possible PM traumas. These included 10 cases, 4 adults and 6 children, for whom the timing, AM or PM, has not been possible to estimate or was not given in documents. The analyzed information is in Table 7. Data on adults and children were treated separately and then collected to constitute total values. Each of these three parts classifies injuries by their significance for the cause of death, and by their relation to the time of death, AM or PM.

Table 7. Injuries of Finnish victims, as found in examinations in Finland

Injuries of the Finnish Tsunami victims

		Head	Extremities		Thorax		Pelvis	Vertebral column			Number
			Upper	Lower	Costae	Others *		Cervical	Thoracic	Lumbar	of cases
Adults	n = 109										
	Trauma as cause of death	4		1	5	2	1	1	1		8
	Trauma as contributing factor	6	1	5	28	9	4	1	3	3	36
	Other peri- or ante-mortem trauma	1	4	2	2	3	6	3	1	6	25
	Post-mortem or possible PM trauma	10	6	5	25	5	4	6	1	8	36
	No injuries										32
Children	n = 55										
	Trauma as cause of death	3		1							4
	Trauma as contributing factor			1	2		1				4
	Other peri- or ante-mortem trauma			1							1
	Post-mortem or possible PM trauma	26	5	16	24	8	7	6	4	4	44
	No injuries										4
Total	n = 164										
	Trauma as cause of death	7		2	5	2	1	1	1		12
	Trauma as contributing factor	6	1	6	30	9	5	1	3	3	40
	Other peri- or ante-mortem trauma	1	4	3	2	3	6	3	1	6	26
	Post-mortem or possible PM trauma	36	11	21	49	13	11	12	5	12	80
	No injuries										36

* = Includes fractures of clavicle, scapula and sternum

Findings in adult victims

The cause of death (CoD) proved to be submersion in 101 adult victims (92.7%). Trauma caused the death in eight cases (7.3 %) (Table 8).

Case 1. A 48-year-old male survivor perished in a Finnish hospital of wide ischemic damage to his brain caused by a thrombus in the left carotic and the middle cerebral artery as consequence of a blunt trauma.

Case 2. A 45-year-old woman's death was as a consequence of cerebral contusion associated with fracture of the frontal bone, and multiple thorax injuries (scapula, clavicle, left ribs, and thoracic vertebrae T3-T4) and cervical vertebrae (C6-C7).

Case 3. The injuries of a 45-year-old man were thoracic fractures and injuries to the aorta and lungs.

Case 4. For this 40-year-old woman, death was due to severe injuries of the head, including multiple skull fractures with a large bone defect (12 x 6 cm), and a hinge fracture extending across both middle cranial fossae, as well as multiple facial bone fractures (maxilla, orbital and zygomatic bones). In this case, fractures of left side ribs (I to IX) and pelvis were considered a contributing CoD on the death certificate.

Case 5. Fatal injuries of a 58-year-old woman consisted of multiple lumbar and bilateral thoracic fractures.

Case 6. A male victim, 52 years old, died of multiple fractures of the thorax.

Case 7. A 41-year-old woman had a fracture of the frontal bone associated with intracerebral lesions as her underlying CoD; bilateral fractures of costae VIII to XI were a contributing CoD.

Case 8. For a 37-year-old woman, dismemberment of her lower leg was the cause of death, including also crush injuries of the thorax leading to damage to several abdominal and thoracic organs.

Injuries to the head totalled 21 cases AM or PM, in 4 being the cause of death.

In six cases, injuries to the head were contributing factors to the cause of death, three of them without fractures. PM or possible PM fractures of the head existed in a total of 10 adult victims.

Injuries to lower extremities were in one case the cause of death, and in five cases contributing factors. In one case, injury to an upper extremity contributed to submersion-based death.

Fractures of the thorax, mainly of the costae, were the most common causes of death (n=5), as well as contributing factors (n=28).

In 26 cases traumas of the thoracic area were estimated to be PM injuries.

In three cases, fractures of the pelvis together with thoracic trauma, and in one fracture of the pubic bone were contributing injuries to the death.

Of the vertebral column fractures, that of the thoracic vertebrae was the cause of death in one case, and three as contributing factors, together with other thoracic trauma. Fractures of lumbar vertebrae appeared in 17 cases. Of these, three were judged to be contributing factors to the death, six non-fatal injuries ante/peri mortem and the remaining eight post mortem. Lumbar fractures were mainly (n=15) connected to other traumas.

Peri/ante mortem injuries, found in 25 victims, were all connected to cases, in which trauma had caused the death or contributed to it.

In 36 adult victims, PM fractures of the head existed in 10 and of the costae in 25 cases. Injuries to the upper extremities had occurred 6 times, and to the lower 5 times, to the thorax (other than the costae) 5, the pelvis 4, and vertebral column 15 times.

Examination of 32 adult victims (32%) confirmed no fractures or serious superficial or internal organ injuries.

In 33 adult cases of death caused by drowning and in 3 cases by trauma, injuries have proven to be contributing factors (Table 8).

Table 8. Number of submersion and trauma-based death cases, and trauma as contributing factor

		Cause of death		Trauma as contributing factor	
	Number	Submersion (%)	Trauma (%)	Submersion	Trauma-based death
Adults	109	101 (92.7)	8 (7.3)	33	3
Children	55	51 (92.7)	4 (7.3)	3	1
Total	164	152 (92.7)	12 (7.3)	36	4

Table 9 presents the underlying cause of death (ICD-10 1992), and in three adult cases the contributing factors for death included also the gender and age of the victims concerned.

Table 9. Fatal injuries of the Finnish victims according to the cause-of-death (CoD) examination performed in Finland (codes according to the ICD-10)

	Female/Male	Age	Underlying CoD	Contributing CoD
Adults				
Case 1	M	48	S15	
Case 2	F	45	S297, S063, S020	
Case 3	M	45	S297	S027, S127
Case 4	F	40	S027	S224, S325
Case 5	F	58	S224, S327	
Case 6	M	52	S297, S271	
Case 7	F	41	S063, S065, S021	S224
Case 8	F	37	S297, S78, S367	
Children				
Case 1	F	13	S822, A480	
Case 2	F	16	S071	S224
Case 3	F	12	S078	
Case 4	F	4	S029, S069	

Findigs in child victims

Of the 165 victims repatriated to Finland, 56 were children. The one victim cremated, does not exist in this analysis.

The CoD proved to be the submersion in 51 cases (93%) (Table 8).

Contributing factors to submersion appeared in three cases. They consisted of fractures of 1) the thorax, 2) pelvis, and 3) lower extremities.

Trauma was the cause of death in four cases (7.3%) (Table 7, 8, 9, 10). Of them, three were head injuries, one involving also fractures of the costae as a contributing factor.

In the first case concerning trauma-based deaths, a 13-year-old girl perished in a Thai hospital after amputation of both legs due to complicated fractures of the left femur and right tibia and fibula.
In the second case (female, 16 years), wide injuries of the face, including fractures of orbital and zygomatic bones, were associated with comminuted fractures of the frontal, parietal, temporal, and occipital bones on the right side. Multiple rib fractures were contributing CoD.
In case three (female, 12 years), multiple bilateral fractures of cranial bones as well as fracture of facial bones were associated with brain injuries. The mandible was fractured vertically between teeth 83 and 82, and the condylar process of the right side was fractured and missing. The maxilla was fractured at midsagittal level; the right side was loosened.
In case four (female, 4 years), wide comminuted fractures existed in frontal, facial and temporal areas. The mandible was fractured vertically in region d.33, and the maxilla was removed. Other facial bones were missing.

Of the 32 cases with fractures of the head and neck, 17 were classified as post mortem and 12 as possible PM traumas.

A fracture of the femur was assessed as a contributing factor in one submersion death; 16 injuries of lower extremities were assessed as PM or possible PM trauma. Of them, 11 occurred eventually by autolysis.

Thoracic trauma involving the costae, thoracic vertebrae, sternum, scapula, and clavicle were frequent (in 28 cases) but only twice as AM traumas: fractures of the costae were judged to be contributing factors to death. One of these cases had serial costa fractures connected to the comminuted cranial and orbital fractures which caused death. The second case was connected with submersion.

In eight cases of fractures of the pelvis, the majority, seven, were PM trauma. In one case, AM trauma of the proximal joint area of the femur was connected with multiple fractures of the pelvis as the contributing factor for submersion.

Injuries of the vertebral column were all PM trauma, ranging from loosened ligaments to seriously fragmented column.

PM trauma of children, promoted by autolysis, existed as multiple findings including opened cranial sutures, thoracic fractures, and changes in the epiphyseal plates of long bones and digits.
PM or possible PM injuries were common findings among children (n=44). Most often the injuries to children included fractures of the head (n=26), costae (n= 24), and lower extremities (n=16). Other parts involved were the upper extremities (n=5), thorax excluding the costae (n=8), pelvis (n=7), and vertebral column (n=14).

Table 10. Underlying and contributing CoD of the Finnish victims repatriated and examined in Finland

	Number	Underlying CoD			Contributing CoD	
		S[1]	IoB[2]	IoHN[3]	IoB	IoHN
Adults	109	101	4+1[4]	3+1[4]	34	6
Children	55	51	1	3	4	-
Total	164	152	6	7	38	6

[1] S = Submersion
[2]IoB = Injury of body, i.e. fatal injuries elsewhere in the body than head and neck
[3]IoHN = Injury of the head and neck, i.e. fatal injuries to the cranium, maxilla, mandibula, teeth, and the cervical part of the vertebral column
[4]One case of an adult include traumas of both the thorax and head as the underlying cause of death.

Findings caused by sampling for DNA

The Standard Operating Procedures (SOP) to apply in the identification operation were amended continuously during the weeks following the catastrophe, and new recommendations and orders were given. Within the first few days, before decomposition, samples of buccal mucosa, hair, and muscle tissue were collected for DNA. Under the TTVI operation, samples of costae and femur were taken during the internal body examination. Additionally, two teeth were extracted.

In Finland, attempts were made to confirm which samples indeed had been taken in diagnosing the defects found in the autopsy, computed tomography, and dental examination.

The first three repatriated adult victims had no indication of DNA samples taken. Altogether, eight bodies returned from Thailand and the only one from Sri Lanka lacked findings of DNA sampling. The most frequent type of sample was teeth, estimated as taken in 94 adult cases (Table 11). Other samples were taken occasionally in the beginning of the operation; of the first 50 repatriated only 12 had samples taken other than teeth.

In children, the estimated number of cases with extracted teeth was 37. The last 20 repatriated had teeth extracted in only 5 cases. A PM missing single-rooted tooth was a common finding, and in many cases it was difficult to estimate whether its absence was due to destruction of the periodontal attachment or extraction for DNA.

The bone most frequently chosen for DNA sampling was the femur (n=93). The costae were chosen in 68 cases. At least two different samples were taken in 90 cases. At least one sample was taken from every child victim (Table 11).

Table 11. DNA Samples from Finnish adult and child victims taken in Thailand

	Number	Costa	Femur	Other	Teeth	Minimum number of samples =1	≥2
Children	54	32	46	2	37	54	41
Adults	107	36	47	1	94	100	49
Total	161	68	93	3	131	154	90

Four cases fail the estimation: of the 56 children one was cremated, and one died in a Thai hospital. Of the 109 adults, one died in Sri Lanka and one in a Finnish hospital.
The ”Other” samples consist twice of humerus and once of sternum.

DISCUSSION

14. Events

The crust of the Earth, or the litosphere, is fragmented into several plates; variations exist in the classification on the basis of their size and number. The seven largest plates (Pacific, North American, Eurasian, African, Antarctic, Indo-Australian, and South American) add up to about 460 million square kilometres, 92 to 94% (Anderson 2002), of the total Earth's surface of about 500 million. The plates move in relation to one another at 2.5 to 15 cm per year (USGS 1999 [1]).

According to the USGS (2009 [12]), it is impossible to predict a major earthquake, and no human activities, even nuclear detonations, have yet been linked to earthquake activity. However, injecting high pressure water or other fluids deep into the faults is known to be able to trigger small earthquakes to occur sooner than in the case without injection.

Variations in magnitude between 9.0 and 9.3 have been noted for the Sumatra-Andaman earthquake. According to Lay et al (2005), its moment magnitude (M_W) was 9.1 to 9.3. Subarya et al (2006) estimates the magnitude (M_W) at 9.1. The United States Geological Survey (USGS 2011 [11]) has also come up with the value 9.1.

A tsunami is a surge caused by earthquakes, volcanic eruptions, or landslides that shake the stability of the mass of water. Tsunamis could be possible to create by such events as nuclear explosions.
The catastrophe concerned was thus unavoidable. No tsunami alarm systems existed. The retreating of the water from the shoreline even hundreds of meters could have appeared as a warning, but most people did not understand this danger sign. On the other hand, because of the rather low terrain, for example in Khao Lak, where 170 of the Finnish victims had accommodations, it was difficult to find a secure place to which to flee.

The concept of a tsunami was unfamiliar to local people. Although the volcanic Sunda Arc has producted some of the most dangerous eruptions, tsunami-like waves this great had not occurred since 1883, when the volcanic island Krakatau exploded.

Although the Pacific Warning Center in Hawaii was alerted soon after the shock (7:59 a.m. Bangkok local time) by a global network of seismic stations, it was not possible to confirm that a deadly tsunami was developing until it hit the nearest coast of Sumatra (Geist et al 2006).
After the 2004 Indian Ocean tsunami, global early-warning systems have been developed. Japan has been a leading nation for both earthquake and tsunami warning systems. The Tohoku earthquake (USGS 2011 [13]) and the subsequent tsunami that occurred on 11 March 2011 in Japan would have been a larger disaster for human victims without an effective warning system. According to the Japan Meteorological Agency (2011), a tsunami warning can be issued within two to three minutes of the earthquake. The Tohoku tsunamis took 10 to 30 minutes to reach the areas first affected. The early warning allowed people to escape to higher inland areas.

15. Tasks and standards of disaster victim identification

15.1. Forensic team and investigations

After a disaster like the tsunami catastrophe involving many countries, the rescue and victim identification procedures ought to start quickly, and the manner of proceeding has to be commonly accepted. The country in which the disaster occurs is responsible for rescue and identification operations. The manner of the proceeding generally follows the jurisdiction of the country concerned. It is, however, recommended to act directly or through Interpol with the governments of the countries concerned. In addition, to obtain AM information, each country may, with permission of the government of the country involved, send experts to participate in the identification operation.

On 12 January, according to a media release on 10 May 2005 (Interpol 2005 [5]), Interpol signed an additional five-year agreement with the Danish Plass Data company. Interpol Secretary General Ronald K. Noble stated that "the need to quickly, and more importantly accurately, identify victims so that they can be returned to their loved ones is always the absolute priority for all DVI teams, and Interpol providing this additional service to our National Central Bureaus in member countries will mean this essential task can be completed with the utmost efficiency."

The identification operation in Thailand following the Interpol DVI protocol showed the importance of a common manner of proceeding for the personnel comprising 2000 experts from 31 countries involved.

The contract of the identification software DVI System International also enables all the188 Interpol member countries to familiarize themselves with international recommendations. In 2009, DVI teams of 34 countries had introduced the DVI System International software for identification purposes.

Several aspects have to be taken into consideration when establishing an expert team to work in a foreign country. One is the question whether the country concerned is willing to utilize or accept the good offices offered. On 28 December 2004, the Government of Thailand made an official request to Finland for assistance in the identification operation. The Government of Japan, however, did not accept the offer of Interpol to assist in the identification operation after the Tohoku earthquake occurred on 11 March 2011.

The consensus with local authority may appear less problematic when the task concerns examination of victims of a natural disaster or traffic accident than of victims of political or ethnic violence. In the latter, the circumstances also influence the security of the team members. In order to prevent and reduce further danger, the disaster site or area must always be secured. The site should be sealed off at a sufficient distance. According to the Interpol DVI Guide, "This enables disaster response forces to work without disruption, ensures the integrity of the evidence and keeps away individuals who have no need or authorization to be present" (Interpol 2009 [2]). The chain-of-custody principles require keeping the number of people involved in data collecting and handling to a minimum.

The team has to take into consideration the legislation of the country concerned, as well as its cultural and religious customs, although these cannot displace the regulations of local and international laws.

After a natural catastrophe, the forensic examination can usually start immediately. The normal task consists of a search for and identification of victims, and determination of the cause and manner, and eventual contributing factors of death. In political conflicts, however, a long time may elapse before the forensic investigation can start. The examination may be more complicated, because the bodies are perhaps more decomposed, and the study has to include the estimation of time since death and, in cases of mass graves, the time since burial. Additionally, the task may include forensic examination of living persons in cases of sexual violence and torture (Rainio 2002). The main task of the forensic investigation team for a war crime court, such as the International Criminal Tribunal for the former Yugoslavia (ICTY), is not victim identification, but to provide evidence concerning the course of events and the cause and manner of death. This information is necessary also to confirm the testimony of witnesses (Takamaa 2008).

The number of experts and their expertise required depends on the extent and type of the disaster. The tasks, the environmental conditions, and the period reserved for the investigation influence the staff and equipment required (Gonzales et al 2005). When the tsunami DVI operation was established, no knowledge of the time duration existed. The active phase took as long as one year; the last Finnish victim was repatriated in January 2006. The total number of Finnish experts in Thailand in 2005 according to the NBI was 115; of these, a total of 12 were forensic odontologists.

A rotation system was obligatory due to the long period, heavy work, and the fact that most forensic medical and dental experts participated in the operation as volunteers, leaving their ordinary duties. The working period ranged from several weeks to two, which was a reasonable minimum to absorb the task and to familiarize oneself with the circumstances. The small number of Finnish forensic odontologists obliged some of them offer their services two, or even several times. A training program for forensic dental qualification, established in 1999, had raised interest in the field. In 2005, the number of recognized Finnish forensic odontologists was 12. Additionally, several dentists had practical experience from former disasters, such as the accident of the *m/s Estonia* in 1994.

Experience at a national or international level varied widely between the 2000 members of the 31 countries (Interpol 2005 [6]) who participated in the identification operation in Thailand during the period 2004-2005. Experience of individuals or teams improves readiness and cooperation under difficult and strange conditions. The processes of investigation are in many respects the same concerning traffic accidents and nature disasters.

The Finnish DVI team, established in 1991 under the National Bureau of Investigation (NBI), has participated in several investigations concerning accidents and criminal incidents. The *m/s Estonia* ferry disaster that claimed 852 victims occurred in 1994 (Soomer et al 2001). Finnish forensic expertise has been applied also in investigations in the Balkan area in 1996-1999 (Rainio 2002, Rainio et al 2001), and in the search for Finnish soldiers buried or missing in World War II. Identification expertise has also been required in two Finnish school shooting homicides that occurred in Jokela in southern Finland in 2007 and in Kauhajoki in western Finland 2008, as well as in two criminal attacks in shopping centers: Myyrmanni 2002, and Sello 2009 in southern Finland.

15.2. Ante-mortem data

The first step in the identification operation is to determine the number and names of persons involved. The tsunami disaster showed characteristics of both open and closed kinds of catastrophes. The names and the places of residence of the tourist bureau customers were registered, but the individual travellers were without contact with any authorities.

The DVI AM Team is tasked with collecting and recording all information relating to individuals who may be regarded as potential disaster victims. Experience gained in previous disaster response operations has shown that "the number of reported presumed victims varies and substantially exceeds the number of actual victims involved" (Interpol 2009 [2]). Continuous updating of the lists kept by the DVI team command can result in a systematic reduction in the presumed number of victims (De Valck 2006). The AM team should not begin to collect AM data until a reliable list of victims is available (Interpol 2010 [2]).

Finnish law contains no exhaustive regulations to forbid or allow the publication of a list of missing persons. Nowadays most industrialized countries share common values including respect for human rights and personal privacy. In Finland, directive 95/46/EC on personal data and free exchange of information is incorporated into the Personal Data Act (Henkilötietolaki 523/1999). According to State Secretary Volanen (2005) it was difficult for the media to understand that the legislation placed strict restrictions on the authorities. After consulting the Ombudsman, the legality of data publication was confirmed. Moreover the common weal was taken into consideration. On 30 December 2004, a list of the missing persons was published on the web site of the NBI. Within a few days, the list reached its final form of 178 names. The Interpol recommendation, not to start collection of AM files until the final number of missing persons has been confirmed, proved applicable: unnecessary examinations of 85 persons were avoided.

It appeared that the list of missing persons included whole families, which caused problems in obtaining AM reference material (De Valck 2006). Of the 172 victims living in Finland, 60 were children (under 18 years). The large number is due to the fact that Thailand has become a popular resort for family holidays.

The teamwork of the Finnish Dental Association and the NBI concerning their patient files was successful: 80% of files were received within one week, and all available (97%) data in one month after the catastrophe.

In Finland, the rehabilitation of edentulousness is a duty both of dental practitioners and special dental technicians. An obvious fault was that the latter group did not receive a request to search their files for AM data. In removable dentures, there seldom exist any identification markings in Finland. This international failing has been noted also in other disasters and studies (Andersen et al 1995, James 2005, Petersen and Kogon 1971). Removable dentures also are easily lost and fragmented in an accident like the tsunami disaster 2004.

The illegible handwriting of medical doctors and dentists is a common concept, and this caused occasional difficulties for the AM analysis. Files based on computer software are already quite common, but the symbols used vary. Some files are based on colored markings, but in many cases they were printed and sent only in black and white.

In general, the dental health of Finnish children is good: caries-free and often orthodontically treated. Thus, after the completion of the dental AM data base it could be expected that for children under 18 dental identification could be established for only 20%.
Even a healthy dentition may display individual details, for example in morphology or dental position, missing, retained, and supernumerary teeth, diastemas, and malocclusion. Such information, however, is useful only if those details are registered in AM documents. Often radiographs can compensate for insufficient information in records. There seldom exist, however, clinical indications for dental radiographs in young children (Fridell 2006).

In Finland, forensic odontologists analyzed the records and radiographs and restored them to the Finnish Human Identification (HUID) programme. HUID was originally designed in the early 1990's and applied in the *m/s Estonia* ferry disaster in 1994. Later, the data base was converted in Finland into the official tsunami victim identification system, DVI System International, of the

Danish Plass Data Company. All of the information was sent via the protected network of the police to Thailand into the Thai Tsunami Victim Identification-Information Management Centre (TTVI-IMC). All radiographs were scanned or photographed digitally, and recorded on a memory stick. Most DVI teams brought their files in paper form and the original radiographs to Thailand. In the AM section of the Information Management Centre, DVI members from police, forensic medicine, and odontology then fed the data on their own missing persons into the DVI System International software. Interpol guidelines oblige the assessment of the dental data by at least two forensic odontologists of the country from where the records are requested. All records submitted and entered via the DVI System International had to be in English. The Interpol Tsunami Evaluation Working Group recommends accepting only original dental records and radiographs. The radiographs may be traditionally developed films or digitally stored data that is transmitted directly to a computer from a radiograph sensor. Although the F1 and F2 (Figure 2) forms were sent electronically, it was required to send to the IMC the original records and radiographs, as well. This request, however, was not followed by all countries.

According to De Valck (2006), the quantity and quality of records of the victims of the tsunami disaster of 2004 were extremely variable across the world, which is mainly due to the differing legislation concerning manner of filing and registration of dental information. According to Kieser et al (2006), members of the New Zealand DVI team, 62% of the hand-written AM records and 54% of the radiographs were of unacceptable quality. In a Scandinavian study (Andersen et al 1995), which handled odontological identification of 292 single fire cases within a period of 10 years in Denmark, Norway, and Sweden, those AM records were classified as excellent in 45% of cases, including detailed written records supplied with systematic radiographs. Dental information was absent from 9% of the cases.

The HUID software will in Finland be replaced by the DVI System International, which already has been used in the identification of Finnish victims of a traffic accident in Malaga, Spain, in 2008.
To increase the efficiency of identification cooperation between the NBI and Department of Forensic Medicine, an internal network connection for the DVI System International has been developed, and will presumably be in use in 2011.

Cooperation between different sectors of the identification: dental, DNA, and fingerprint should already be taken into consideration in the phase of AM data collection. As a generally approved rule, AM material for all identification methods should be available, although part of the information collected later often appears unnecessary for the final identification. The applicability of different identification methods varies, depending on the type of the disaster and also on those persons concerned. Knowledge of the type of the disaster and the availability of AM data would aid in concentration on the most effective identification methods. In cases where the victims are badly burned, the fingerprint method is probably not the best alternative.

The dental AM data collected after the tsunami from the missing persons' files were evaluated according to their value for the identification. It became apparent that the children seldom, only in 20% of the cases, had sufficient dental information for an established identification. The collection of AM reference samples for the fingerprint and DNA analysis could have been directed with higher priority to these cases instead of to adults, of whom 86% were predicted to be identified by dental records.

The tsunami disaster, however, clearly demonstrates that all means of identification should proceed actively from the start until the case is considered closed. Cooperation would progress better, if specialists from different sections of the identification would familiarize themselves with each others' methods and operation models.

15.3. Post-mortem data

According to Sribanditmongkol and colleagues (2005), a search for bodies began, after the operation to rescue survivors, by the local government, the army, and volunteer teams of charity foundations. In default of a centralized command, teams set up their temporary morgues mostly in Buddhist temples. The search teams did not number the bodies nor register the place of discovery. In the absence of refrigerated containers or other preservation facilities, the forensic teams had to act quickly. The conditions improved on 3 January as the operation moved to Site 1a, Wat Yan Yao in Phang Nga province. The dental findings were ordered to be incorporated in Interpol forms. Teeth and jaws were photographed. Bite wing radiographs were taken and other pictures at the discretion of dentists. Two teeth were extracted for DNA samples. No exact instructions were given for the numbering of bodies, but the telephone country code of the examination team was added.

Meyer et al (2006) reported on the resolution of the Austrian DVI team to avoid problems caused by non-readable body markings. This team implanted radio-frequency identification device (RFID) microchips, 12 mm in length, into bodies. This chip, coded with an identification number, was placed with an injector usually into the maxillary sinus. The information on the chip could be decoded by a battery-powered reader from a distance up to 15 cm. According to the report, any felt-tip pen markings would dissolve due to embalming (formalin) and antiseptic (lysol) fluids. Further, in crowded cold-storage containers the reading of identification numbers was difficult. Interpol did not put this microchip-method into common practice in the TTVI operation.

Under Thai law, a forensic investigation is required for deaths caused by accidents. In general, the purpose of the investigation is to identify the victim and to determine the time, place, cause, and manner of death. In the case of the tsunami disaster, the main purpose of the forensic investigation was the identification (Sribanditmongkol et al 2005). According to a commonly accepted principle, an investigation of the cause of death, besides the identification, should be performed on every victim found. The World Health Organization (WHO) has listed causes of death in the WHO's International Classification of Diseases (ICD-10 1992). This classification that originated in the 1850s is in use in all 27 (in 2010) countries of the European Union (EU), and is recommended to all WHO member countries, altogether 193 (2010). Concerning such an unexpected catastrophe with so vast dimensions, it was impossible to follow this principle completely. It was reasonable to concentrate on the comparison of the 3574 AM files and 3681 PM files registered in Thailand, and leave the decision concerning the cause-of-death investigation to each country concerned.

Despite the recommendations, different practices have been applied in various catastrophes concerning the medico-legal examinations.

Prieto et al (2007), concerning the Madrid terrorist bomb attack in 2004, report that complete autopsies were not carried out except for a few of the 191 victims, because "external examination in the great majority of cases enabled the determination of the cause of death." Additionally, they pointed out that "complete autopsies could have provided relevant data of interest in the forensic pathology area, but given the characteristics of the disaster, the prime objective at all times was to identify victims aiming to avoid as far as possible the uncertainty and anxiety experienced by the families awaiting news about their missing loved ones."

Concerning an air crash in France in 1992, Ludes et al (1994) report that full autopsies were performed on all victims to determine the patterns of injuries and the cause of death. These autopsies, however, were not performed until AM information came from families regarding the morphological characteristics useful for the identification by macroscopic or radiological examination.

In his report concerning an aircraft accident in Milan in 2001, Lunetta et al (2003) report that all the four Finnish victims, not autopsied in Italy, underwent a full forensic examination after the repatriation including re-examinations for DNA and dental identification.

The Thailand Tsunami Victim Identification (TTVI) operation, established by the Royal Thai Government together with Interpol, included an agreement to use Interpol DVI guidelines in the identification procedures. The manner of forensic proceedings thereby became established.

The forensic medical research included, besides an external, also an internal investigation to discover besides the gender, the presence of the appendix and gallbladder, any possible pregnancy, and other individual characteristics, congenital or caused by diseases or medical operations, and to obtain samples for DNA research (Westen et al 2008). Breast implants were removed for identification purposes.

For the DNA, multiple samples were necessary because of the deteriorating condition of the bodies, and due to the fact that DNA samples were sent to different laboratories. Altogether, 295 samples were taken for DNA from those 161 Finnish victims that were found and identified in Thailand and repatriated to Finland (Table 11). The wounds arising from these, as well as from the forensic internal and dental investigations, were often left unsutured. The Recommendation on the harmonization of medico-legal autopsy rules (Council of Europe 1999) emphasizes that after a medico-legal autopsy the body has to be released in a dignified condition. According to the Interpol DVI Guide (Interpol 2009 [2]) it is essential to ensure that only unavoidable changes are made to the bodies examined during the PM investigation. It might be easy to explain that the fast progress of the identification required compromises of some ethical principles. Perhaps some teams have considered the opening wounds minor compared to the injuries caused by the accident and by decomposition. Some operations have been criticized as having been unnecessarily invasive. For fingerprints, for example, the hands of 11 Finnish adult and three child victims were removed; in one case the hands remained missing.

For the dental identification, resections of jaws by sawing were performed on 21 Finnish victims: 17 adults and 4 children. In four cases one or both jaws were lost, which, besides being ethically unacceptable, made dental identification impossible, and also broke principles concerning the preservation of all collected material. In her communication concerning DVI protocols and quality assurance in PM data collection, Kvaal (2006) states that neither jaws nor parts thereof should be removed from the remainder of the body. Additionally, if any material has to be removed for further (e.g. DNA) examination, it has to be clearly labeled, appropriately stored, and a note placed in the PM records as to where the material is being kept.

Discussion has arisen also concerning the need for and methods of exposing the jaws for dental examination. The Interpol Tsunami Evaluation Working Group points out in its recommendation number 63 in *The DVI Response to the South East Asian Tsunami between December 2004 and February 2006* that "in DVI operations it is not necessary or culturally acceptable that both jaws (mandible and maxilla) are extracted and removed from the body. Evidence from the TTVI operation showed that in the few cases where this had been done, the jaws could not be retrieved for re-examination and considerable delay occurred."
Both jaws were resected from 12 Finnish adult victims and one child; in two adult cases they remained missing. So it is presumable that resections were performed in more than a few cases.
It was a common practice to disarticulate the mandible in its entirety for dental examination. Due to the incision performed below the jaw, as well as reposition of the mandible and adequate suturing after the examination, the operation did not leave considerable signs.

For dental data, Interpol forms were completed with the symbols of the DVI System International by Plass Data. Teeth were photographed, besides from the projections ordered earlier, also from a frontal view. Besides bitewings, radiographs were taken of teeth otherwise informative, like those with root canal fillings that seemed to keep their white color whereas vital teeth in many cases had changed to pink. Radiographs were also taken for age assessment of children. In the new DVI guide (Interpol 2010 [2]), Interpol suggests taking radiographs as follows: molars on both sides with jaws together (bite wings); upper and lower molars, and possibly premolars and incisors (periapicals); teeth with special features, such as root canals and crowns; and other radiographs as required.

The difficult circumstances particularly at the early stage of the operation bore risks for occupational welfare and health. Due to the inadequate hygiene conditions at Site 1 and the rapidly proceeding decomposition of the bodies as well as the normal tropical circumstances, some mandatory vaccinations besides anti-malarial treatment were required. These were for hepatitis A and B, diphtheria, tetanus, meningitis, typhoid, and polio. Protective clothing, gloves, masks, and eyewear were included in the normal examination equipment. In the hot environment, heat stroke and dehydration were potential problems, as well. Concerning the Finnish DVI team, these protective measures were carried out effectively.

At the early stage of the identification operation one disturbing factor constituted the visitors and other outsiders who, without limitations, were allowed to remain in the area.

The long distance requiring 2 to 3 hours of travel to Site 1 from the place of residence at Karon beach in Phuket caused disadvantages for personnel welfare and shortened the effective daily working time. The working days became long, and in the absence of any rotation system no holidays were available. These inconveniences were lessened as the new Mai Khao Cemetery, Site 2, in Phuket Province was opened on 29 January 2005. The time to travel to the Site shortened to one hour.

The teams on the body examination lines were either national groups or combinations of international experts. The Finnish team included members of all specialties: autopsy technicians, forensic odontologists and forensic pathologists, as well as police experts for fingerprints, photographs, and documentation of personal belongings. The teamwork appeared fluent due to familiarity regarding members, language, and manner of proceeding.

The great majority of the bodies examined were badly decomposed, some nearly skeletonized. Under favorable conditions, this procedure will usually take two to four weeks. According to Mann et al (1990), the greatest effect on the rate of the decomposition is from temperature. The second most important factors are insects and their larvae, which cause the majority of the soft tissue destruction. They favor the warm and humid conditions that existed in the tsunami surroundings. Additionally, the position of the bodies on the surface of the ground, and their light clothing promoted the decay process. Bodies with penetrating wounds, which appeared to be common findings, will be destroyed faster than intact ones in otherwise similar circumstances. Studies have not proven that neither the size or weight of a body nor gender would play any role in the rate of decay. In warm and humid conditions, such as in the tsunami disaster, only a few seconds may pass before the first flies land on a superficially positioned dead body. As proof of insect activity, the body bags usually contained masses of dead larvae.

15.4. Identification

The right of everyone to an identity is a pronouncement of the Universal Declaration of Human Rights of the United Nations (1948). All the 192 member countries of the UN are bound to follow this principle.

In their book concerning the law in war, Rosén and Parkkari (1993) state that respect for those killed in action is one of the oldest traditions of war, and is closely linked to the advancement of humanity of the country concerned.

The identification procedure serves, besides being an official operation, also as a humanitarian service to the deceased (Hutt et al 1995, Ludes et al 1994). For the relatives, the certainty of death of their loved one allows the start of the grief work. After the forensic examination, and when all evidence has been collected for identification, the responsible forensic pathologist may give permission to release the body for funeral proceedings. The proof of identity in death cases is essential also for various legal procedures concerning for example pension, insurance, and estate distribution. K.A.Brown (1988) wrote:" It requires action and financial support by the governments of every country to establish within their borders a central identification agency and procedures that are internationally compatible. Well organized protocols will not only expedite the identification process and improve morale of the personnel involved, but more importantly, will project an image of professionalism that will inspire the confidence of the relatives of the deceased, thus minimizing their mental trauma and distress."

In Thailand, within the first days after the catastrophe, about 500 bodies were identified at the scene by their families and released by the local authority. Besides these, about 1 100 victims' bodies examined by Thai forensic teams were released before the TTVI operation (Sribanditmongkol et al 2005). Identification was confirmed mainly by external appearance and physical evidence. Petju et al (2007) report that the number of bodies released was in total approximately 1 600. According to TTVI-IMC International Commander Forest (2008), over 2 000 bodies were released in the first few days based on visual identification. Many of these may have been incorrect identifications, however.

Interpol (2010 [4]) counts the number of bodies released before the TTVI operation based on the difference between the official number of missing persons in Thailand as 5 395, and the final num-

ber of PM files as 3 681 in the DVI System International. The difference shows that 1 714 bodies should have been released. Most of those were identified by visual and physical evidence.
According to the above information, 1600 to 2000 bodies may have been released without evidence based on primary methods of identification.

Visual identification has proven unreliable even in cases when the death has occurred recently and the identifier is a close relative. Injuries to faces and changes in appearance caused by death as well as the emotional upset of the relative may lead to mistakes. Interpol points out that "the primary and most reliable means of identification are fingerprint analysis, comparative dental analysis, and DNA analysis;" and secondary means include "personal description, medical findings as well as evidence and clothing found on the body. These means of identification serve to support identification by other means and are ordinarily not sufficient as a sole means of identification" (Interpol DVI Guide 2010 [2]). The Interpol Tsunami Evaluation Working Group points out in its recommendation number 45 in *The DVI Response to the South East Asian Tsunami between December 2004 and February 2006* that "the use of visual identification methods in mass fatality incidents is considered unreliable and almost certainly will lead to incorrect release of bodies."

In recommendation 46 concerning identification strategies, the primary methods include besides dental, DNA, and fingerprints also *unique medical condition* as one new alternative. To introduce a medical or physical condition as identification evidence requires the thorough knowledge and the long clinical experience of the forensic pathologist. Uniqueness is difficult to evaluate. The Finnish examiners were very careful in their pronouncements. The medical and physical characteristics were classified as supporting evidence for the identification.

The identification method of choice depends not only on the type of accident or event, but also on the condition of individual victims. For the identification, there must be available expertise in all kinds of methods (Ludes et al 1994). At the stage of the PM body examination, there may not yet be knowledge of what kind of AM data will be available. Later, comparison PM material may be more difficult or impossible to obtain. The collection of PM data or samples for identification is necessary even if AM data are unavailable, because the collected material may later become useful for other purposes (Rainio 2002). The collected material, if unnecessary for identification, may still be useful for the accident investigation committee, whose task is to resolve the causes, results, and the progress of the accident to prevent similar events. For the police, the information received from the forensic examination may be important for crime investigation, as well.

The primary identification methods have their own characteristics that are applicable in different situations (Table 12). Owsley et al (1993) point out that the more injured the body, the fewer methods for identification remain.

Table 12. Selected characteristics of primary methods of identification

	Dental	**DNA**	**Fingerprint**
Individuality	Variable	Individual	Individual
Lifetime change	Continuous change	Stabile	Stabile
Age assessment possible	Yes	No	No
Gender specificity	Yes/no	Yes	No
Reliability for identification	Variable	Reliable	Variable
Availability of comparison data for identification	AM files available for most people	Various registers Samples from the environment and relatives	Increasing registration (passports) Samples from the environment
Disadvantages	Files sometimes difficult to locate Variable quality Data possibly insufficient for identification	Contamination Cross-checking to exclude outsiders	Soft tissues easily destroyed Cross-checking to exclude outsiders
Advantages	Good preservation	Samples available from various tissues Small amounts needed Determination of minimum number of victims, and identification of body parts	Samples available from fingers, palms and feet

In their report concerning a train accident in Åsta, Norway, Rognum et al (2000) state that when the identity has been established by one method, the work with other methods should be discontinued. This way the identification becomes secured without unnecessary delay. This principle of effectiveness in the identification procedure is in concordance with the efforts of the TTVI and with the investigation of the Madrid terrorist attack (Prieto et al 2007). Moody and Busuttil (1994), however, recommend in their report concerning the Lockerbie air disaster using all identification methods available. They learned that even when the identification evidence was sufficient for the authorities, it did not always convince the relatives. The air disaster with 270 victims was exceptionally difficult to investigate, because the explosion occurred at height of 31 000 feet (9 450 m), and remains were scattered over an area of 845 square miles (2 200 km^2).

In the tsunami disaster, identity of the repatriated victims was confirmed in Finland based on fingerprints, DNA, dental data, and once on physical properties, verified by DNA. According to the reports of the Finnish Identification Board, no discrepancies existed between the identity results received in Thailand and Finland, although the identification methods chosen differed in 18 cases.

The applicability of methods of identification differed among various countries. According to the analysis by Petju et al (2007) based on the TTVI-IMC database that was updated in December 2005, dental identification was applied primarily to European adult victims. Most victims from North America, Oceania and Africa were also identified by dental evidence. The significance of the fingerprint method increased considerably, being the principal method from May to October 2005. The great number of victims identified by fingerprints comprise mostly Thai and other Asian nationals. For successful fingerprint identification, Thailand has an official register of fingerprints for use on identity cards (Schuller-Götzburg 2007).

After difficulties at the start, the applicability of DNA comparison increased, becoming the most useful method from October especially for child victims as well as for badly damaged and decayed bodies.

Various methods are sometimes required to complete the identification. For example, dental or skeletal age-assessment or fingerprint analysis may help to distinguish siblings of the same sex, which is impossible via DNA identification based on samples received from their parents. The Finnish victims were members of 75 families. Of them, 42 included more than one missing person, and 32 families persons of at least two generations. (Palo 2010). For the DNA identification of children, reference samples were available from their deceased parents, but not until they were identified. In Thailand, most of the DNA matches were supplemented with physical or other additional evidence to discern children of the same families (Interpol 2010 [4]).

In an open disaster with badly injured and fragmented bodies, DNA analysis has proven effective for identification, but it also helps to show the minimum number of individuals who perished in that disaster. DNA also represents a useful method in situations, when remains are too few for other identification methods (Ludes et al 1994, Mannucci et al 1995, Budimlija et al 2003) .

Additionally, in child cases when dental evidence is poor, DNA has been applied successfully. Of the Finnish tsunami child victims (n=55), 26 were identified by DNA in Finland, of adults (n=109) only six.

Despite the bad condition of the bodies, a very high success rate, over 95%, was achieved in recovering the DNA profiles in PM examinations in Finland (Palo et al 2005). This finding reveals the importance of the adequate chain of custody (ENSFI 2008), beginning with specimen sampling and handling without contamination.

In December 2005, when approximately 80% of the 3 750 victims were identified in Thailand, DNA was applied in 20% of the cases, fingerprints in 35%, and dental methods in 45% (Interpol 2005 [6]). For Thai nationals, the respective values were 39%, 59%, and 2%, (Petju et al 2007).

The number of identifications in Finland by fingerprints was at about the same rate as by DNA: children in 24 of the 55 cases, and adults in 7 of 109.

Concerning fingerprints, the success even in badly decomposed cases was in great part due to the hot-water method, which according to informal information was applied in the World Trade Center disaster investigation. In Thailand, it was presented by the US team.

The applicability of identification methods applied to adults differed from those applied to children. Differences between genders, however, did not exist concerning samplings for DNA and fingerprint methods. Although difficulties in PM sampling resulted from decomposition, no studies have shown that gender would play any role in the rate of decay (Mann et al 1990).

Concerning dental information, possible gender-based differences could have emerged as to the availability of AM reference data. Females have proven to be more active in their own dental health

care. According to a study of the *National Institute of Health and Welfare* "Health and functional capacity in Finland; baseline results of the Health 2000 health examination survey," the number of annual visits to dentists of female Finns was 1.7 and of male Finns 1.3 (Nordblad et al 2002).
All those five Finns lacking dental AM files were males, but one of them was an elderly almost toothless man, three were small children, aged 1, 2, and 4, and the fifth was a middle-aged man negligent in his dental health care.

In dental identifications in Finland, problems arose from missing jaws in four cases, a missing head in one case, and by cremation of one child victim, as well as by extracted and otherwise missing teeth. Extractions were performed for DNA in an estimated 131 cases. The teeth were mostly intact, and thus did not include indispensable evidence for the identification. Concerning children, however, the most usual teeth extracted, the lower canines, would have been essential for the most practicable age-assessment method of Demirjian et al (1973).

Different opinions exist concerning the type and number of teeth to extract for DNA. According to Kvaal (2006), one tooth may be extracted if required for further (DNA) analysis, but front teeth or canines only in exceptional circumstances. Before extraction, the original dentition must be be documented not only by records, but also by photographs and radiographs.

Westen et al (2008) recommend removing one intact tooth, preferably a canine, an upper incisor, or a molar. For DNA analysis the intact tooth with the largest pulp cavity is preferred, because this should yield the largest amount of amplifiable DNA. The dimension of the pulp cavity depends on the size of the tooth and is age-dependent as a result of secondary dentine deposition. In children, open roots make the teeth much more susceptible to contamination and to DNA destruction.

The sampling strategy of the International Commission on Missing Persons (ICMP 2008) to obtain the best possible dental samples for DNA profiling requires extraction of at least two well-preserved teeth; caries free and without restorations. Teeth with completely formed root apices are recommended but not absolutely required. The best alternative is the first molar, followed by the second and third molar, the first and second premolar, canine, and incisor. The instructions include the recording of dental information for the extracted teeth for identification.

The Interpol DVI guide (Interpol 2010 [2]) recommends extracting healthy teeth, preferably molars, for DNA.

For the extraction of multirooted teeth, clinical experience is required to avoid damaging crowns or roots, which may lead to exposure and contamination of pulpal tissue.

The dental identification in Finland was performed by one forensic odontologist. Of the 165 repatriated victims, 100 were examined by one dentist (the author), and the rest by his four colleagues. Each manner of proceeding was similar, but each examiner had to evaluate individually the result of the identification. For the final resolution, differing opinions may exist mainly between the grades *established* and *probable*. There existed borderline cases especially in the dentitions of young people, whose healthy and in many cases orthodontically treated teeth included very few personal characteristics. No discrepancies occurred, if the identification was *established* or *probable*, but the latter required supplementary evidence for the final identification.

The one-dentist method was chosen for practical reasons, and did not cause problems. Interpol, however, proposes in its DVI guide (Interpol 2010 [2]) as a rule that two dentists should cooperate in the recording of the dental status of the body and in producing radiographic and photographic records. The team includes a forensic odontologist as the clinical examiner and a forensic odontologist or an assistant for registration. The International Organization for Forensic Odonto-Stomatology (IOFOS) suggests that forensic odontologists should work in pairs checking on each other and thus acting as quality control. This kind of procedure also affects work regarding the hygiene between the clinical examination and registration of findings.

Any problem concerning hygienic conditions was avoided in the dental examination with the help of a hands-free dictating machine. Possible mistakes in mutual communication concerning markings in dental registration were also avoided.

In children, the age-assessment methods were chosen case by case based on the developmental status and the condition of the victim. Problems were caused in eruption-based assessment methods by the decomposition of gingival soft tissues, and in development-based methods by missing teeth. In 30 cases of child victims, the Finnish identification board has noted age assessment as a supporting factor for identification.

In adults, the assessment of age was in most cases not essential for the identification. The age, however, has to be in concordance with other PM evidence. Therefore, the age was assessed by weighing several changes linked with age found clinically and in radiographs. An example of alternative methods is the radiological method of Kvaal et al (1995), based on changes in pulpal

dimensions. The method of Bang and Ramm (1970) is based on the width of the translucent dental periapical zone caused by the mineralization of the dentin. The Lamendin method (Lamendin et al 1992) is based, besides on the translucent zone, also on the length of the periodontal attachment. These last two methods are applicable in cases of mass disasters with several victims and in field work. They are quick to perform and require no special equipment (Soomer et al 2003).
Of skeletal methods, a radiological method based on the developmental stage of the epiphysis of the clavicle is applicable up to the age of 27 years (Kreitner et al 1998). The pubic joint of the pelvis and the rate of ossification of the lateral-anterior sutures of the bones of the skull (Meindl-Lovejoy 1985) have also been applied to age estimations in adults.

The prediction of dental identification of Finnish victims based on AM data is in concordance with the results received from the verification of the identification performed in Finland (Table 13). Differences result partly from the different number of missing persons and repatriated victims.
The percentage difference shows that the prediction has been estimated more conservatively; this is evident for example in the results *established* and *probable* in adults. The table also shows that the PM examination was performed effectively. The manner of proceeding, physical examination, and data recording operated well. It reveals also that dental structures remained in good condition although the bodies were in advanced decomposition.

Table 13. Dental identification of Finnish victims (combining Tables 2 and 5)

		Number	Established (%)	Probable (%)	Possible (%)	No data (%)
Prediction	Adults	112	96 (85.7)	6 (5.4)	8 (7.1)	2 (1.8)
	Under 18	60	12 (20)	9 (15)	36 (60)	3 (5)
	Total	172	108 (62.8)	15 (8.7)	44 (25.6)	5 (2.9)
Final identification	Adults	109	98 (89.9)	2 (1.8)	5 (4.6)	4 (3.7)
	Under 18	56	14 (25)	19 (33.9)	20 (35.7)	3 (5.4)
	Total	165	112 (67.9)	21 (12.7)	25 (15.2)	7 (4.2)

Prediction is based on AM data, and final identification on AM/PM comparison.
PM data have come from dental examinations in Finland.

15.5. Investigation of cause of death

The recommendation on the harmonization of medico-legal autopsy rules (Council of Europe 1999) states that all member states carry out autopsies, but not all have specific and appropriate legislation regulating that issue. In some states, the most relevant aspects of an autopsy are covered by criminal law, while in other states, rules relating to autopsy procedures are incorporated in specific medico-legal legislation. As a rule, national law governs the Interpol DVI directions.
Differences in the manner of carrying out forensic investigations, for example in accident cases, may lead to additional and duplicate investigations. This causes expense, and delay in the release of victims for burial.

In Finland, the Act of the Inquest into the Cause of Death (Laki kuolemansyyn selvittämisestä 459/1973) and amendment of the law concerning investigation of cause of death (1997) oblige the police to perform an investigation when it is known that death has not been caused by disease, or when the deceased during his last illness has not been treated by a physician, when death has been caused by crime, accident, suicide, poisoning, occupational disease, or medical treatment, or when there is reason to suspect that death has resulted from such a cause, or death has been otherwise unexpected. When the order for a medico-legal autopsy is given, it also includes investigations for the identification, if there is any doubt about the identity of the victim.

When bodies are decomposed or skeletonized, as in the tsunami catastrophe due to the wet and hot conditions, estimation of vitality of the injuries can be difficult or impossible (Mann and Owsley 1992, Rainio 2002). There may be injuries which have not caused the death but may otherwise serve as important evidence for the estimation of the manner and circumstances of death.

The conditions were extremely damaging for the bodies both ante/peri-mortem and post-mortem. Although the cause of death in 93% of the victims was submersion, only 22% (n=36) remained uninjured. Presumably, during the surging stage of the tsunami waves, 12 Finns were hurt fatally. Additionally, in 40 victims, the injuries were so grave that these were assessed as contributing factors to death.

PM traumata were common findings (n=80) especially in children, who were involved in 44 cases. It is possible for PM traumata to have arisen also when bodies were excavated from the ruins. Besides physical trauma, also autolysis has induced injuries quickly in warm and wet conditions. PM trauma of children, promoted by autolysis, existed as multiple findings including opened cranial sutures, thoracic fractures, and changes in the epiphyseal plates of long bones and digits. Assessment of the vitality of injuries is difficult or even impossible. The estimated PM injuries included 10 cases, 4 adults and 6 children, in whom the timing of injuries was impossible to estimate or was not commented upon in any documents. These injuries did had no influence on the cause of death, which was the submersion.

Pink color was a common finding in vital teeth in the dental PM examination. Medico-legal interest had arisen due to their possible causal connection with the cause of death. Pink teeth were documented the first time in 1829 by Thomas Bell in cadavers of those dead from drowning, hanging, strangling, and from asphyxiation (Clark and Law 1984). According to Borrman et al (1994) this color seldom occurs earlier than one to two weeks after death. Incidence of this phenomenon has been linked to asphyxia more often than to other forms of unnatural death. Humid conditions are often a common factor. Borrman et al (1994), and also Soriano et al (2009) state that the cause is the rapidly increased blood pressure, hyperemia, and hemorrhage in the dental pulp chamber. The study of Clark and Law (1984) showed that the color results from a breakdown product of the hemoglobin, protoporphyrin, located in dentinal tubules. The reason why this phenomenon takes place only occasionally under identical conditions has remained unknown.

16. Limitations and adverse factors in the identification

For the identification, limitations exist both at the AM and PM level. Additionally, some circumstances exist that an individual researcher or the team cannot influence. Despite these, the team is expected to complete the identification procedure as effectively and as quickly as possible.

AM data form the basis for the conclusion, which means that even the most exact PM evidence cannot lead to an *established* result if the AM records are sufficient only for the identification category of *possible*.

According to Kieser et al (2006), 62% of the AM records received for the identification of tsunami victims from New Zealand were of unacceptable quality, and in 64% of the cases, radiographs were lacking or were of poor quality. Brannon and Kessler (1999), in their analysis of 50 mass disasters in which of a total of 2 416 victims, 79% had been identified by dental methods, report that inadequate records and radiographs characterized the majority of the data received. In many cases, AM information failed, because some persons seemed not to have had a dentist and, surprisingly, some dentists refused to cooperate and release their records. In disasters, data in the victims' possession may also be lost, or records may be filed in clinics destroyed in the disaster (Brannon and Kessler 1999). In some cases, the incident may have damaged or destroyed the country's existing emergency-response infrastructure, making the task of victim identification even more difficult.

The availability of dental AM data for the Finnish tsunami investigation was good, leaving only five persons without information. Except for the illegible writing, the quality of the markings in the files was acceptable concerning dental treatment performed. Updated and accurate status markings of individual details, for example in morphology and dental position, would, however, have produced important additional data concerning young people who usually have only a few restorations. It is understandable that clinical practitioners do not consider such kinds of markings significant in normal dental health care.

To obtain AM information it is essential to know the number and names of persons involved. This task is easier for the authorities in closed accidents, like airline disasters with passenger lists, than in open disasters, such as the tsunami catastrophe. Air accidents also often have an open component of victims who perished in the crash area. The tsunami disaster also had characteristics of a closed type of accident due to the customer lists of travel bureaus.

In accidents, the bodies often are damaged, sometimes badly destroyed. For identification, it is most important to collect all human remains. Forensic odontologists and anthropologists should therefore participate in the accident site investigation as members of the Recovery and Evidence Collection Team (Vale et al 1977 and 1987, and Hutt et al 1995). Odontologists are trained to recognize and differentiate dental and jaw particles.

Whole-body radiographs have been recommended to discover dental structures that have been displaced into other tissues (Petersen and Kogon 1971).

The good preservation of dental structures comes out in the report of Petju et al (2007) concerning the condition of the tsunami victims. Of 3 750 dead bodies examined in 2005, only 98 (2.6%) had injuries too destructive for a dental examination.

Due to the decomposition of the periodontal tissues, single-rooted teeth easily became loose and disappeared, thus reducing the reliability of dental PM data for identification and age assessment purposes.

Andersen et al (1995) describe in their study concerning fire victims the good preservation of dental structures for identification purposes. In 50% of fire victims (approximately 70% house fires) the teeth were not injured, and in 25% injuries existed in anterior teeth only.

Facilities for an adequate investigation should be available. In cases that include several victims or when the accident has occurred in an isolated location, it is rather reasonable to transport the deceased to a institute provided with trained personnel and adequate equipment.

The investigation of victims is intensive work. The task comes unexpectedly and as an additional load on the team members' normal routine. Police, relatives, and the media expect results quickly.

Conditions for psychological stress are many. According to Jones (1985), methods exist to minimize this problem. New team members are recommended to work in pairs with more experienced colleagues. Use of respectful, considerate humor is suitable to lighten the atmosphere. Rotation of tasks has been suggested, but some dentists seem to be more familiar with body examinations, while others would prefer to work on tasks concerning AM data and comparisons. Rotation, however, to keep individual working periods within moderate limitations, is necessary, if sufficient staff are available. There should be an opportunity for private or group discussions with a psychologist. In Finnish tsunami examinations this, however, was seldom necessary.

Dailey (1995) reports that inexperience has proven to be a source of errors. All examination results should be checked and accessed by more experienced team members before further handling. Errors in AM or PM forms may be classified, first, as critical errors, which can lead to misidentification or false exclusion, or second, as moderate errors, which require resolution of any differences noted, causing additional and time-consuming work. A minor error does not influence the identification result, but still has to be taken into consideration in the comparison. The forensic odontologists are responsible for the interpretation of the AM files and for the PM examination. False markings in patient records by the practicing dentist may also lead to misidentification, if the error cannot be corrected, for example with the aid of radiographs. In the report of Kieser et al (2005), PM forms, completed in connection with the dental examination were variable in quality, although the manner of proceeding was already established. That study was based on data received from 16 January to 7 February. To complete the requirements of good practice, the team ought to include a forensic odontologist as quality controller in order to accept the forms, photographs, and radiographs.

Several years may be pass between the last dental visit recorded in the AM files and the time of death. Within this period, it is possible that the person has received treatment from another dentist, or the dentition has degenerated for lack of health care. In that case, the forensic dentist must be able to evaluate, whether the differences between AM and PM information constitute a logical chain of events.

There exists no minimum number of concordant characteristics in AM and PM dental data required for establishment of identification by dental information. A single tooth containing unique features may be sufficient for identification, whereas full dentition without restorations and AM markings of personal characteristics may contain enough information only for an identification grade of possible.

The DVI System International was unfamiliar to many odontologists; it required working in pairs for quality control. The database also allowed some dental information, like missing teeth, to be coded by different symbols. If the same information were coded differently in AM and PM files, the program could not interpret the match, which caused delay in the identification process. One problem, later corrected, was that for the comparison, having AM and PM radiographs or photographs shown on the screen at the same time was impossible.

As for written information, poor knowledge of English was sometimes a source of error.

Use of digital methods could have produced radiographs of better quality in the PM examination. Direct input into the identification software also had saved time.

Tooth-colored restorative materials have proven to cause errors or at least difficulties in a PM examination. Fillings made with care are difficult to detect, but failure in color selection or negligent finishing makes them easier to detect. Further recommended methods for successful detection include the use of an effective spotlight and loupe. A device sending ultraviolet light, preferably at variable wave lengths, may bring the fillings out in a different color from the surrounding dental tissue. Modern restorative composite materials are also detectable in radiographs. Tooth extractions, done to facilitate the recognition of restorations, have been applied in some investigations (Moody and Busuttil 1994).

Pretty and Sweet (2001) have described unusual methods applied for identification in situations with poor evidence. Dental prostheses are seldom provided with the patient's name or with any identity number. For identification, recovered dentures have been fitted to plaster casts retained by the dentist, the laboratory, or the patient. Removable orthodontic braces have also been useful for the same purposes. If AM plaster models are available, impressions of palatal rugae have served as comparison evidence.

Unique medical condition has been accepted as an additional alternative for primary identification evidence. This, however, requires clinical experience to evaluate the uniqueness of the condition concerned. For an example, among the adult male Finnish victims, numbering altogether 55, were two cases, each of whom had the second toe of his right foot amputated.

The dental PM examination is difficult to perform if the victim is badly burned, or if *rigor mortis* still prevails. Opening the mouth is prevented due to the stiffened muscles. The situation becomes easier if the autopsy has been performed before the dental examination. The absence of the tongue offers more room for the inspection. Usually, however, the identification is the most urgent task. In the case of shooting homicides occurring in southern Finland in November 2007, a schoolboy killed, besides himself, also six students and two school staff members. Identifications were performed originally by dental panoramic tomographs because of *rigor mortis*. The dental clinical examination for PM data was performed during the following two days in connection with each autopsy.

In single cases, when bodies are found without any supposition as to identity, identification is impossible due to the lack of AM data. A national dental database of missing persons would be helpful for a rapid and successful comparison after the PM examination. According to the NBI, some 20 to 30 Finns remain missing yearly. In Australia, where each year approximately 30 000 people are reported missing, the majority temporarily, Missing Persons Units have been established (Blau et al 2006). The criterion to furnish a dental database may be a "suspected death," disappearance under suspicious circumstances, or a set length of time to be missing, for example for 60 days.

If AM dental records are unavailable due to the lack of any indication as to the deceased's identity, the PM examination is still important in order to limit candidates. The profiling may produce information on age, gender, socio-economic status, ethnic origin, and sometimes systemic diseases. According to Pretty and Sweet (2001), it may be possible to provide additional information regarding occupation, dietary habits, and habitual behaviors. The origin of some unknown bodies found in Finland is thought to be the southern and eastern neighboring countries, based on the differing manner and materials applied in dental health care there.

17. Future outlook

On 13 January 2005, the Finnish government appointed a Major Accident Investigation Committee under section 1 of the Accident Investigation Act (Laki onnettomuuksien tutkinnasta 373/1985). According to the Accident Investigation Board of Finland, the purpose of the investigation of accidents is to improve safety and prevent future accidents.

The flow of events, the causes and effects of the accident, and the rescue operations were all to be investigated. The final report, A 2/2004 Y (Major Accident Investigation Committee 2005), gives an account of the reasons for the disaster and the sequence of events, and presents recommendations to minimize damage resulting from similar future accidents.

The committee stated that readiness of authority to take immediate measures to help Finnish nationals in mass disasters occurring in foreign countries was insufficient.
The committee recommended that the government clarify the need and methods to amend legislation concerning personal data-handling, to avoid problems in rescue, evacuation, and assistance tasks, to gain sufficient information without violating individual rights.

The organization and equipment of the DVI team were not dimensioned for an operation so large and long-lasting. Lack of funds and of experienced personnel made it difficult to recruit replacements for work in Thailand.

The DVI group consists of experts in several professions working both in governmental and private sectors. Their detachment from their regular professions often for an indefinable period requires existing plans and contracts regarding wages, insurance, and health care. Moreover, the flow of information, initiation into the operation, and rotation require organization.
The total number of Finnish experts in Thailand in 2005 was 115. Approximately 200 experts have worked within Finland in tasks concerning victim identification. The Ministry of the Interior has been requested to increase the efficiency of the DVI team by a continuous financing.

On 30 December 2004, a new law (Laki siviilihenkilöstön osallistumisesta kriisinhallintaan 1287/2004) was promulgated to facilitate the participation of civilian experts in international teamwork concerning examinations in mass disasters or convulsions of nature. The task rests with the Ministry of the Interior and the Ministry for Foreign Affairs. Qualifications required for the ministries are to recruit, educate, equip, and to monitor the employment of the staff concerned. Their rights and duties follow the requirements of the law of civil servants (Valtion virkamieslaki 750/1994). The Ministry of the Interior maintains a register of civilian experts to use for occasional tasks in Finland and in foreign countries.

Practicing dentists, 4 800 in number, were involved in the tsunami catastrophe examination via the request to investigate their files for AM information. This rare task was suitable to discover defects in data registration to be corrected for the future.

There is general agreement as to the success of the identification operation involved in the Asian disaster in December 2004. The communication and teamwork between DVI teams of different countries will become easier in the future based on the common guidelines of Interpol. As an example of this, the Danish identification software DVI System International by Plass Data, adopted by Interpol and applied in the TTVI operation, is already in use in 34 countries. (Hurskainen 2009).

The project of an internal network connection between the NBI and Department of Forensic Medicine, with its purpose to increase the efficiency of identification cooperation, is still unfinished in 2011.

The Interpol Tsunami Evaluation Working Group suggests in its recommendation number 61 in *The DVI Response to the South East Asian Tsunami between December 2004 and February 2006* "to use digital techniques as a tool for the future. The various DVI-related data should all be digitally recorded, i.e. dental information, fingerprints, medical findings, property, and forensic police evidence. The quality will increase, and it will be easier to enter this information into the DVI System International."

The Royal Thai Government is currently in the process of developing its national structure for disaster response. According to an official in the Department of Disaster Prevention and Mitigation (DDPM), the Civil Defense Act of 1979 will be superseded by a new act. The aim of this act is to consolidate the national capacity to respond to disaster emergencies by improving the role of the DDPM as the central coordinator. The new act will also improve the capacity of local government to plan, prepare, and respond to emergencies. An updated National Disaster Management Plan is also currently developing under control of the DDPM (IFRC 2005).

Many analysts have claimed that the disaster would have been mitigated had there been an effective warning system such as the Pacific Tsunami Warning Center, established in 1949 in Hawaii.
The Indian Ocean Tsunami Warning System has been established to provide warning of approaching tsunamis to inhabitants of nations bordering the Indian Ocean. It was agreed to in a United Nations conference held in January 2005 in Kobe, Japan, as an initial step towards an International

Early Warning Programme. The system became active in late June 2006 following the leadership of the United Nations Educational, Scientific and Cultural Organization (UNESCO). It comprises 25 seismographic stations relaying information to 26 national tsunami information centers, as well as three deep-ocean sensors.

SUMMARY

The Sumatra-Andaman earthquake was the strongest since 1964, when the second strongest ever measured (M 9.2) took place on the opposite side of the Earth, in Prince William Sound, Alaska.
The depth of the Indian Ocean at the epicenter was 4 000 meters, which caused a most destructive tsunami wave.

Both the earthquake and the tsunami were unexpected and uncommon phenomena of nature for people in the disaster area.

Caused by the direction of the edges of the tectonic plates, the waves surged to the nearby long coastline of Sumatra and the northern part of the Malay Peninsula. Of the total of 179 Finnish victims, 170 were located in Khao Lak, which was the most badly destroyed area in Thailand.

The tourist season in Thailand lasts from November till April, and is most active in holiday weeks, such as the Christmas season.

Visitors in Thailand had no reason to expect such a disaster. The authority in Finland could have had no influence on the number of victims after the disaster occurred.

After the rescue of the living, the main operation consisted of a search for and identification of the deceased, the manner of which generally follows the jurisdiction of the country concerned.
In Thailand, during the first days after the disaster, when the bodies were not yet decomposed, several hundreds were identified visually by their families and released by local authorities. Under Thai law, a forensic investigation is required in deaths occurring in mass disasters. In general, the purpose of an investigation is to identify the victims and to determine the time and place of death as well as the cause and manner of death.

To fulfil these requirements, international teamwork was necessary. Due to the lack of forensic expertise in Thailand, and the great number of victims, of which a great proportion were foreigners, Thai authorities and Interpol set up the Thai Tsunami Victim Identification (TTVI) operation to

assist in the identification of all victims without any discrimination as to race or ethnicity, in order that all victims' bodies could be returned to their loved ones.

Teams working in the disaster areas used the internationally accepted Interpol DVI protocol, which enabled officials from all over the world to use the same criteria and compare data more efficiently. The key function of the TTVI operation was to collect AM and PM information from DVI examination teams and input it into a central database for matching and subsequent identification.

The DVI System International identification software, which proved successful in the TTVI operation and has been accepted for official use in Interpol, has in Finland replaced the HUID identification programme.

The overall rate of identification of the tsunami victims processed by the TTVI (2006) is 86%. Of the 179 Finnish nationals who perished in the catastrophe, five persons (2.8%) are still missing.

Limitations in dental identification caused the lack of AM files for five missing persons and the intact dentition of several children and adolescents. Loss of teeth due to the decomposition and extractions for DNA caused difficulties in identification and dental age assessment.

Of Finnish adult victims, the dental identification method was successful in 90%. For children, identification by DNA and fingerprints was more applicable. Dental identification was established in 25% of child victims.

At the national level, the Finnish DVI team deserves recognition also for the additional tasks performed after the repatriation. Each victim underwent a complete forensic investigation including verification of the identification. Besides the conventional radiological methods, computed tomography, used in post mortem investigations in Finland, proved of utmost value in the cause-of-death investigation.

The most common cause of death of adults and children proved to be submersion, in 152 (92.7%) of the 164 Finnish victims repatriated. Injuries were proven to be contributing factors in 36 submersion-based deaths and in 4 trauma-based deaths. Trauma was the cause of death in 12 cases.

Prior to the Southeast Asian tsunami disaster, forensic dentistry in Thailand had played only a minor role in the forensic sciences, and no national standards or guidelines had been established.

In Finland, due to the education program in forensic odontology, established in 1999, the number of officially registered forensic odontologists was increased to 12 in 2005, which enabled the rotation in Thailand for the whole year, as well as staff to perform the tasks in Finland concerning AM data collection and the identification after the repatriation.

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Olli Varkkola

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