Chapter 8

Forensic Odontology

Teeth and Their Secrets

Helena Soomer, DDS, PhD

1. Introduction

When I was a little girl, I enjoyed playing puzzle games. Although fitting many small pieces carefully together may take some time and effort, the result is always fascinating—a big and truly unique picture! Forensic science is like that. By working with these “puzzle pieces”—the pieces of evidence from a crime scene—the “big picture” almost always results. The resulting picture is a provable reconstruction of what happened, how it happened, and most importantly, who did it. This reconstruction work is done by a team of forensic specialists. They work together at the crime scene to recover, document, collect, and transport the resulting evidence to the crime laboratory for further analysis. Each expert has special skills in his or her area of expertise. The forensic odontologists on these teams are dentists who have such special skills in the areas of forensic dental science, including criminal investigation and identification. They analyze any dental evidence, make forensic conclusions, and testify in court to support their conclusions. Forensic odontologists often play an essential role in identifying either victims of disasters or victims and suspects of individual crimes. They thereby assist the legal authorities in solving crimes and bringing criminals to justice. Forensic odontologists have other roles as well. For example, their activities may range from assisting in archaeological expeditions to assessing bite marks and injuries to the teeth and facial structures for plaintiffs in civil and criminal cases.

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2. WHO IS THE FORENSIC ODONTOLOGIST?

The forensic odontologist is first and foremost a highly trained clinical dentist, familiar with tooth development, oral anatomy, disease pathology, and dental surgery and restoration. The forensic odontologist combines this specialized clinical knowledge with additional investigative skills. For example, the odontologist is trained in collecting evidence and working closely with police investigators and the medical examiner. The forensic odontologist is familiar with the standards for evidence recovery, documentation, and analysis, such as the International Criminal Police Organization (Interpol) standards for victim identification. Thus, forensic odontology crosses the disciplines of clinical dentistry, forensic medicine, and police investigation.

3. WHAT IS DENTAL EVIDENCE?

Dental evidence may include such diverse items as a bite mark impression, the entire dentition of a victim, or just a single fragment of a tooth found at a crime scene. Dental evidence also includes the premortem, or historical evidence of dental treatment, such as textual records, diagrams, and X-rays. Because teeth are the hardest materials of the human body and strongly resist postmortem changes and adverse environmental conditions such as fire, water immersion, or explosion, dental evidence is often available in crime cases. Consequently, forensic odontologists play a vital role in investigations.

For example, our team was once called to the scene of a murder where we found a fractured tooth in a pool of blood next to a murdered man. The forensic odontologist immediately recognized the unique morphological features of this tooth fragment and identified it as the upper left second molar. However, the victim had his second molar, and indeed all 32 of his teeth, in place. The odontologist surmised that the tooth probably belonged to the assailant, who must have been injured severely to lose such a large and firmly rooted tooth so deep in the mouth. Therefore, all emergency medical facilities in the region were alerted to be on the look out for a recent traumatic facial injury. In fact, one hospital had just received a patient who had sustained a gunshot wound to his face. He claimed to have been wounded while cleaning his gun. Our forensic team rushed to the hospital and asked for his panoramic mouth X-ray. The X-ray revealed that, in addition to his other facial injuries from the gunshot, the patient was freshly missing a second molar—consistent with the tooth we found at the crime scene. The patient tried to escape from the hospital after receiving first aid, but was arrested at the door for suspicion of murder. In this case, the forensic odontologist quickly identified the criminal, who would have otherwise escaped early capture. The type of identification procedure described here is called "comparative identification," which consists of the forensic comparison of a person's known dental data (the panoramic mouth X-ray in this case) and the dental evidence found at the crime scene. The result is a determination of whether the dental evidence came from the known person (the suspect in this case). This example shows how the forensic odontologist can play a crucial role in a breaking crime scene investigation.

4. Scope of Forensic Odontology

Forensic odontology is broadly applicable to criminal investigation, disaster recovery, and civil law cases. Identification of unknown persons is a main focus of forensic odontology. However, forensic odontologists also participate in a wide variety of activities, including scientific research and even in the investigation of ancient civilizations and peoples.

4.1. Identification Work

Identification is one cornerstone of forensic odontology. Whether it involves estimating the age of an illegal immigrant detained in a terrorism investigation without documents, matching victim remains to premortem records in a mass disaster, or identifying a single crime victim, forensic odontologists spend most of their time trying to answer identity questions: Who is the victim with the dental bridge and a missing molar? Who is the criminal who left that bite mark? How old is that detained terrorist?

4.2. Age Estimation

Age estimation helped solve a recent European case where a man was tortured and then murdered in a brutal fashion: his hands were tied and he had received multiple flesh wounds before finally dying. After the murder, the criminal tried to hide the crime by burning the victim. As a result the victim was unrecognizable: the outer layer—hair, skin, and clothing—was completely burned away. However, the teeth were preserved because they are the hardest parts of the body. This victim had shining white teeth, which led the policemen and forensic pathologist in attendance to agree that he must have been young. Fortunately, the forensic odontologist was also in attendance and recognized that the "nice white teeth" were in fact artificial—covered by expensive porcelain veneer. The rear teeth were worn and had moderate periodontal disease. Dental age estimation by the forensic odontologist provided a completely different victim profile: this man was approx 50 yr old and was likely someone wealthy enough to have this expensive veneer work done.

In this investigation the forensic odontologist correctly recognized and correlated a variety of interrelated factors: the normal dental anatomy, the presence of subtle blended restorations, and the age-related pathology and wear patterns. This technique is called "reconstructive postmortem dental profiling." With reconstructive profiling, dental evidence collected from the body is used to determine the victim's profile, including factors such as approximate chronological age, social status (e.g., expensive restorations imply wealth), smoking and dietary habits, and even sex and race.

Dental age estimation is a common dental forensic procedure. It can be done upon intact teeth, as demonstrated in the preceding case, or even more precisely by sectioning the teeth and examining them microscopically. The microscopic exam typically assesses features such as the amount of secondary dentine (a reparative tissue), increased root transparency, root resorption, and the amount of cementum around the root—all of which increase directly with age. The gross appearance of the wear patterns and other microscopic findings are all directly related to a person's age. Several formulae have been derived to calculate age based on these observations and measurements *(1–6)*. The application of reliable dental age estimation techniques *(7)*, as well as assessment of other associated dental features, permit the police to narrow their search among missing persons and, therefore, identify murder or disaster victims more quickly and effectively *(8)*.

4.3. Disaster Identification

Forensic odontologists are crucial team members when investigating small- and large-scale disasters. Dental identification is quick, highly accurate, cost-effective, and can be done on site in most cases. In contrast to other techniques, such as DNA identification, it requires only minimal equipment and logistical support. Typical requirements include electrical power, X-ray equipment, and a computer assisted identification program, such as WinID or Interpol's Disaster Victim Identification (DVI) System, when large amounts of victim data are involved. DNA analysis is a powerful adjunct technique as well, but it is not possible in all cases. For example, just as premortem dental records may be missing, premortem DNA samples may not be available. In some other cases the postmortem DNA may be degraded or contaminated, such as in the case of the fractured tooth mentioned earlier, where the DNA-rich pulp has been exposed to and contaminated with an unknown blood source. However, as that case also showed, the anatomy of the same tooth fragment may be all that is needed to provide an immediately available and crucial clue that can result in an arrest. DNA analysis also requires considerable time, often weeks or even months, because multiple postmortem samples and premortem reference samples must be processed *(9)*. In many cases DNA and dental identification compliment and confirm each other.

4.3.1. Mass Disasters

4.3.1.1. September 11th Attacks

The notorious terrorist attacks on September 11, 2001 included the World Trade Center in New York City. At this location, 2752 deaths were recorded *(10)*. The victims virtually all received severe trauma and therefore more than 19,900 body parts were recovered. Approximately 1435 victims have been positively identified. The main methods of identification were DNA (more than 700 cases), dental (more than 500) and fingerprints (approx 200). In addition, dental identification contributed in 78% of the cases where some other means of identification was conclusive *(10)*. A dental contribution to identification typically meant that there were no discrepancies between ante- and postmortem dental data, but that the dental data alone was not sufficient by itself for positive identification. For example, the dental identification was deemed to contribute if premortem dental information was not unique (e.g., could match several victims, as might be the case if only textual dental records were available and no dental X-rays). Another example of dental identification being contributory was when the premortem dental data was relatively complete but there was only limited amount of postmortem information (e.g., only a small piece of jaw or just one tooth). Dental identification was able to play such an important role in the September 11th disaster in part because premortem dental records in the United States were, generally, highly complete and readily available.

In order to handle the huge amount of data, forensic odontologists working on the September 11th disaster used a computerized dental identification system called WinID. WinID is a database that stores ante- and postmortem dental information about physical descriptors, pathological injuries, and anthropologic findings. These findings are used to match missing persons to the unidentified victims. *(11)*. WinID is one of several available forensic dental computer systems. For example, Interpol offers another computerized identification system that is used in Europe called the DVI system. Unlike WinID, DVI not only has dental identification capabilities, but also is a general purpose forensic tool to store and match other data, such as information about the victim's overall physical description, autopsy findings, personal belongings, DNA profile, etc. Computerized systems have become increasingly important in mass disasters, wherein dozens, hundreds, or even thousands of potential premortem data sets must be matched to postmortem data sets.

Although September 11th is particularly memorable because of the human and economic scale, other mass disasters occur with dismaying frequency. Although airline crashes come to mind most readily, wartime crimes, such as those in Kosovo *(12)* in the mid 1990s, ship or ferry disasters and natural disasters are also significant. Airline and other transportation disasters are particularly notorious and difficult to deal with, perhaps because of their unexpected occurrence and frequently multinational implications. The severe trauma these victims often undergo also presents particular challenges to forensic teams.

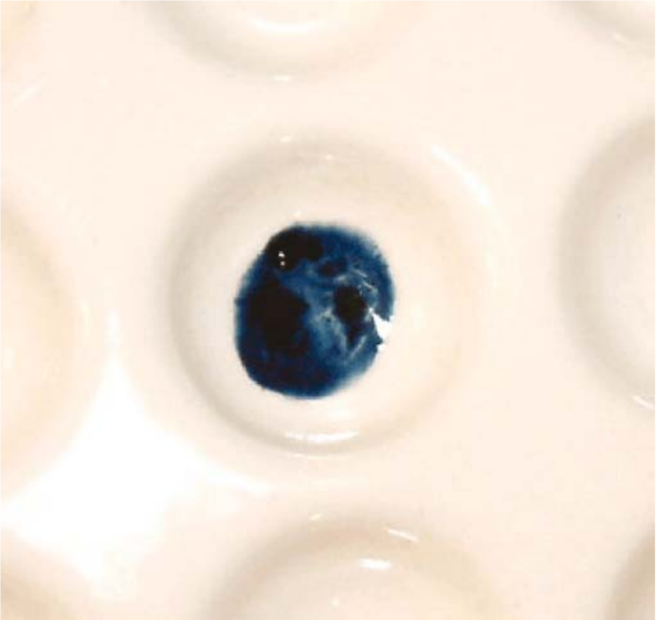
4.3.1.2. SAS 686 Crash, Milan, Italy

On October 8, 2001, at Linate Airport in Milan, Italy, an SAS MD87 airplane with 110 crewmembers and passengers on board was ready to take off. It was cleared to reposition itself onto the active runway, but simultaneously a Cessna Citation II jet with two pilots and two passengers on board was taking off on the same runway. Seconds later these two airplanes collided and crashed into an airport baggage hangar, causing the death of four additional victims among the ground staff. The planes caught fire and large pieces of airplane wreckage and multiple body parts flew into the air. Firefighters and rescue crews rushed to the scene, but nobody had survived. The accident claimed a total of 118 victims of nine nationalities *(13)*.

Following this accident, DVI teams from the respective countries involved began work. Some "home" teams stayed in the passengers' countries of origin and collected premortem data, whereas other teams arrived on site to collect postmortem data. Using passenger lists from the airline, the odontologists back in the home countries worked in pairs (checking each others' work) in order to collect and enter all available premortem dental data from dental records into the Interpol DVI system. The on-site teams simultaneously entered the postmortem data into the same system. The DVI software allowed the team members to match the pre- and postmortem data and produce possible matches. I was in Copenhagen at the time and joined the Danish DVI home team in collecting premortem data.

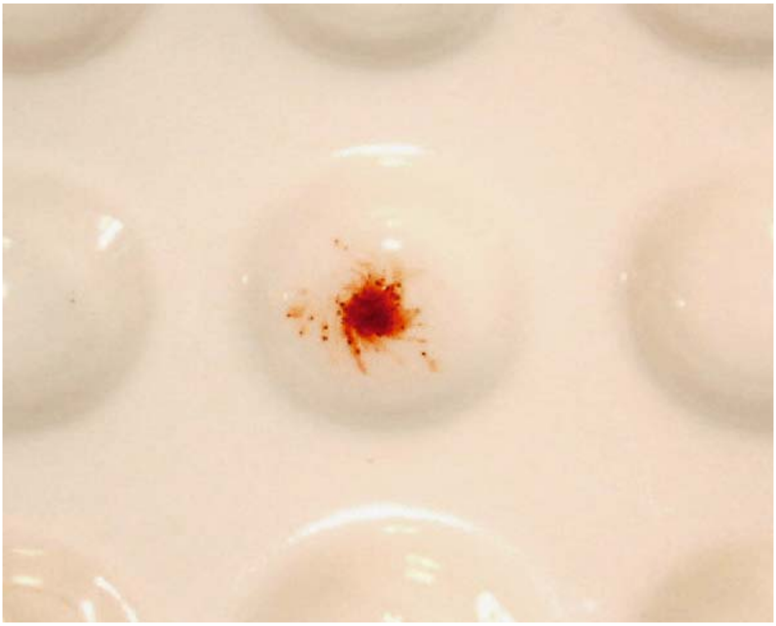
This multinational disaster in Milan involving nine different countries demonstrated several important points. First, forensic odontologists must be familiar with different countries' dental record keeping systems (including legal standards). Dental record-keeping standards in different countries vary widely, far beyond the obvious language differences. Some countries, such as Sweden, have elaborate clinical documentation requirements, whereas other countries have no particular requirements beyond legal minimum standards for billing *(14)*. Second, dental conventions and standards used in the dental record also vary widely. For example, European dental records refer to the right lower third

Color Plate 1, Fig. 5. Original version of micro-taggants. (*See* discussion in Ch. 5 on p. 94).



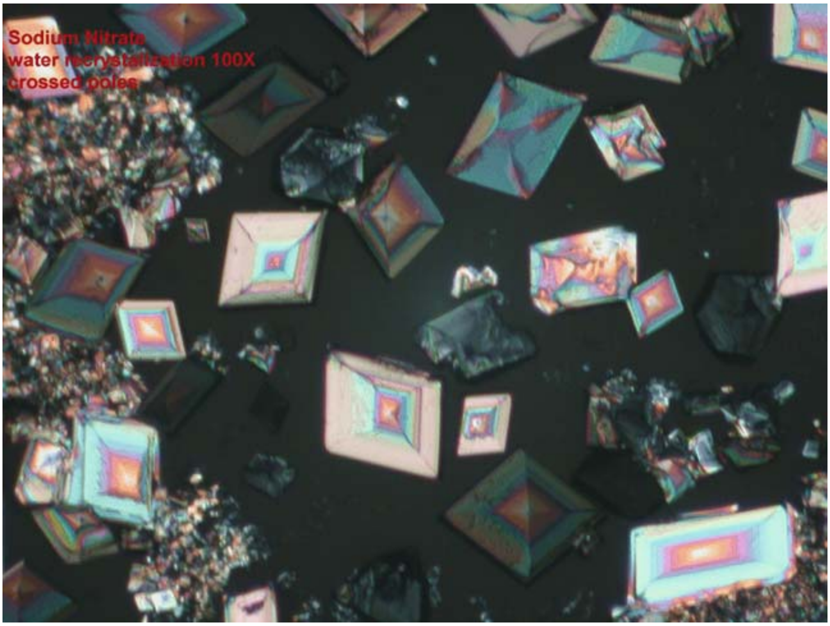
Color Plate 1, Fig. 12. Diphenylamine color test. (*See* discussion in Ch. 5 on p. 98).

Color Plate 2, Fig. 13. Anatazoline color test. (*See* discussion in Ch. 5 on p. 98).



Color Plate 2, Fig. 14. KOH color tests. (*See* discussion in Ch. 5 on p. 98).

Color Plate 3, Fig. 17. TNT fusion melt. (*See* discussion in Ch. 5 on p. 102).



Color Plate 3, Fig. 18. Sodium nitrate under crossed poles. (*See* discussion in Ch. 5 on p. 102).

molar as tooth number 48, but in the United States it is called tooth number 32. Forensic odontologists must be aware of these different standards and the various terminology systems used. Third, the Milan disaster also indicates the need for forensic odontologists to reach agreement on international standards to collect premortem and postmortem information, such as the Interpol DVI system and WinID that were previously described. The Interpol DVI system is particularly useful because it serves to integrate the victims' dental, pathological, anthropological attributes (e.g., clothing, documents, jewelry), and personal information. Systems, such as Interpol DVI and WinID, allow the evidence to be combined and viewed in a single system. Both systems also permit remote, on-line collaboration by premortem "home" teams that are physically separated from the on-site teams.

4.3.1.3. Scandinavian Star Ferry Fire

The Scandinavian Star was a European ferry that in 1990 experienced a disastrous arson-caused fire at sea resulting in 158 deaths. Many victims could not be visually identified because they were burned beyond recognition. A team of forensic investigators, including forensic odontologists, was called up to secure evidence for identification. In this case, the fire was so intense and long lasting that some remains were partly ashed, and even the teeth (that usually resist fire) had started to degrade. Because the remains were so fragile, it was crucially important that the odontologists were able to work on site in order to preserve the dental evidence (e.g., by spraying the remaining teeth with fixatives). Otherwise, as the evidence was recovered, documented, and packed for transportation it might well have been accidentally destroyed. The four forensic dental teams involved in the Scandinavian Star accident were based at Institute of Forensic Medicine at the University of Oslo in Norway. These teams used the Interpol DVI forms in their work and all victims were positively identified within 17 d. Dental identity was positively established in 107 cases (68% of the total victims) *(15)*. In cases such as these, dental identification has proven to be extremely effective and reliable.

4.3.2. Interpol's Role in Mass Disasters

Interpol is a global organization of 182 countries whose mission is to prevent and combat international crime and to assist in international mass disasters. I have interned at Interpol headquarters, located in Lyon, France. Interpol sets standards and also identifies, coordinates, and assists national and international forensic teams. The agency provides member countries with necessary resources such as the computerized Interpol DVI system. Interpol also sponsors symposia and meetings for DVI teams where the latest forensic techniques are presented. In summary, Interpol provides a support network for the forensic experts in different countries, so that they can work together more effectively.

In addition to its work assisting DVI teams, Interpol maintains and publishes databases that help governments find missing persons and identify unknown victims. Interpol also provides a network of secure computer databases that are accessible to member countries' law enforcement agencies. These databases include data concerning criminal intelligence information (e.g., trends in international crimes), the modus operandi of various criminal and terrorist networks, and information about variety of police support activities. Interpol's databases and reference collections also encompass comprehensive examples of genuine and fraudulent travel documents (i.e., passports) and currency forgery examples. Finally, Interpol provides a conduit to disseminate information about fugitives and missing persons. Interpol staff members are top-level experts in various areas of policing and forensic sciences. Forensic odontologists and forensic teams should take advantage of Interpol's resources, particularly in the case of disasters or crimes involving international participants. It is important that all law enforcement agencies, including forensic teams, work together in an effort to create a safer world.

5. Police Cases

Although mass disasters are prominent news stories, the daily work of forensic odontologists involves assisting in the solution of every day police cases. Suppose, for example, that an old person lives alone and one day his neighbor calls the police because he has not seen him for many days. Then the police and forensic pathologist would go to the house and perhaps find a partly decomposed body in bed. In this case the identity may still be in question, and then the forensic odontologist would be called to verify the old person's identity based on his dental records. This type of work is the bread and butter of forensic odontology. Although this might be termed an ordinary case, the forensic odontologist also becomes involved with fascinating and even notorious criminal cases.

5.1. The Case of an Ambitious Surgeon

In one case I participated in, a well-known female surgeon from a prestigious hospital was suspected of murder. She had an unambitious husband who had lost his job, was known to abuse alcohol, and was reportedly violent. One day she reported her husband was missing. Police started an intensive search. A black garbage bag was found near the victim's home that contained an upper human torso. Soon afterwards another bag was found containing the lower torso. Body parts kept turning up in a gruesome fashion: 1 wk later legs and arms were found and, finally, the head. These body parts were unusual in that they were precisely cut, as if in a medical amputation. In order to verify the victim's identity, the forensic odontologist examined the teeth and compared the findings to the missing man's dental record. Every detail matched, and the missing husband was therefore quickly identified. The wife was later found guilty in this case.

5.2. The Case of a Missing Teen

Sometimes an unusual dental injury or condition can provide the crucial clue needed to establish identity. For example, I participated in one case involving a missing teenage girl who had disappeared without a trace after a birthday party. One year later some skeletonized remains were found, but they were badly eroded because the remains were in a gravel pit. The teeth were the only remains in good condition because (as previously mentioned) they are the most resistant tissues in the human body. Some of these particular teeth were stained in a characteristic pattern—a horizontal, gray line in the enamel—consistent with childhood exposure to tetracycline, an antibiotic normally not given to children. Indeed, medical records showed that the missing girl had accidentally received tetracycline at about 7 yr of age. The stains in the skeletal teeth were in those permanent teeth that would have developed at about age 7. This case shows that teeth may have particular characteristics, such as discoloration owing to antibiotics, which provide relatively unique and important dental evidence that can solve the case.

5.3. The Case of the Pink Teeth

Another example of unusually colored teeth was the result of a postmortem cause, not premortem damage. This was the "case of the pink teeth." Some townspeople came across a set of teeth on a nice spring day when the sun was shining and the resulting snowmelt uncovered a corpse on the bank of a local river. Police were then called to the scene and uncovered a partially skeletonized body with shoes and jacket still on. The male corpse was brought to the morgue for autopsy, where it was found that one of the most remarkable features was that the teeth were pink. The jacket included a wallet and driver's license, indicating that the corpse was that of a taxi driver who had gone missing the previous fall. Therefore, although identification was not in question, the mechanism of death was. The body was partly skeletonized and there was no obvious bullet wound or trauma. However, the pink teeth strongly suggested a death by strangulation. The phenomenon of pink teeth is typically produced by engorgement of the pulp and dentin of the tooth with blood. This can occur when venous pressure in head is raised, such as during strangulation or choking. When this happens the erythrocytes (red blood cells) are released into the tooth's pulp and dentin. Development of this appearance takes a long time after death, as the erythrocytes must decay, and the decay process is aided by a wet environment. These factors were both present in this case *(16)*. The presence of the pink teeth led the forensic pathologist to more closely examine the hyoid bone ("Adam's apple"), which was fractured in a manner consistent with strangulation. The suspect—a late evening passenger—finally confessed that he had strangled the driver from behind in order to take the last of that day's fares.

6. Injury Analysis

Another cornerstone of forensic odontology is the analysis of injuries. These include bite marks on a victim or a suspect, facial injuries in criminal and civil cases, and malpractice cases. For example, who committed that sexual assault and bit the victim? Did the victim bite back, and, in that case, do the suspect's injuries match the victim's teeth? Was someone's dental injury really caused by that bar fight, or was it pre-existing? These are the sorts of injury questions forensic odontologists answer.

6.1. Bite Marks

One unique branch of forensic dentistry attempts to match a victim's bite mark to the unique dentition of a suspect. These cases are not uncommon. For example, one case involved a young woman who had just left a party and was on her way home. She matched the profile for being a good target: walking alone on a quiet street, distracted by using her cell phone, had long hair that was easy to grab, and was wearing high heels (making it hard to run away). She was later found sexually assaulted and murdered, and a severe and distinctive bite mark was found on one breast. The mark was particularly distinctive because it was an indented, three-dimensional mark. That showed that the bite had been inflicted at the time of death (postmortem) or even shortly after death. If the woman had been alive for even a short time afterwards, the normal reaction of live tissue would have caused the mark to become raised. The finding of the three-dimensional bite mark is significant because it tells us that the person who bit the woman was present and in physical contact with the woman at the time of her death and most likely also responsible for the death. In this case the forensic odontologist who examined this mark matched it to the unique misalignment of the suspect's teeth. The suspect was subsequently arrested, convicted, and sentenced to lifetime imprisonment.

6.2. Facial and Dental Injuries in Civil or Criminal Trauma

Dental injuries occur relatively frequently in family disputes, brawls, and gang fights. The forensic odontologist is sometimes called to determine how the dental injury happened (the trauma mechanism) and what damage was incurred. The forensic odontologist provides evidence that may show who is to blame for the injury, so that a court may subsequently rule who is to pay the costs of the treatment and suffering. For example, in one case I have seen, a man claimed that his front teeth were kicked out in a recent fight. He attempted to get compensation for his injuries from his alleged assailant. However, our examination showed that this "victim" had severe periodontal disease that likely explained the missing teeth, and dental X-rays showed that the bone around the teeth had long been healed. In this case the claim was clearly fraudulent, although that fact would not necessarily be obvious to a lay jury or even to a treating physician. Forensic odontologists are frequently called on to validate assault cases or civil lawsuits for trauma or injury, and they can often provide conclusive testimony.

6.3. Malpractice Cases

Forensic odontologists also take part in malpractice cases. These cases often involve some long-term treatment that has had a poor result. For example, an orthodontic treatment may result in undesirable alignment of the teeth. Malpractice cases can also result from a failure to diagnose. For example, the treating dentist may fail to recognize a cavity. If that cavity then gets bigger and reaches pulp chamber, the tooth often requires root canal treatment and an extensive crown, instead of just a simple filling. In these cases the patient may ask for compensation and the forensic odontologist may be asked to provide evidence.

6.4. Anthropology and Archaeology

Anthropology is also an important field in forensic odontology—and one with surprising applications to criminal cases as well. There was a news report indicating that three sets of fetal remains were discovered in an attic during remodeling. Were these children stillborn, or born alive and then murdered? The forensic odontologist may be called on to provide that answer, and they may do it using the same anthropological techniques used to assess the age and health status of ancient children.

Forensic odontologists may work in collaboration with archeologists to examine persons that are long dead, such as ancient peoples whose remains are uncovered in archeological digs. For example, I have been involved in several anthropological projects involving investigation of skeletal remains of the Middle Helladic period (approx 2000–1700 BCE). These projects involved ancient peoples from the Lerna and Asine areas of ancient Greece, nearby present day Nauplion, Greece. I worked closely with both archaeologists and anthropologists to estimate the age and health of ancient individuals based on their dental remains *(17)*. In the Asine and Lerna studies, the main focus was on children and even fetuses. The death rate was high among young children and infants in ancient Greece. In this study, a subject's health and nutritional status was estimated by examining the extent of dental enamel hypoplasias. Hypoplasias are visible both grossly (when severe) and microscopically. These lesions indicate a reduction in enamel growth, usually resulting from severe illness or malnutrition, which are conditions of great concern to anthropologists.

The anthropologist in this study also wished to determine whether the infant skeletons represented live births or stillbirths. Many infants in the Middle Helladic period were probably stillborn. I was able to estimate whether a fetus had been born alive or was stillborn by determining the presence or absence of the "neonatal line." The neonatal line is similar to an enamel hypoplasia, but represents the changes in dental growth that occur acutely at birth instead of changes related to illness later in childhood. Thus, infants who are stillborn lack the neonatal line because they have not undergone the birth process. The presence or absence of the line is determined by microscopic examination of a sectioned tooth. Such a technique has obvious applications in criminal cases, as indicated in the attic example.

7. How to Become a Forensic Odontologist

Few degree programs in forensic odontology exist, so formal education is not always easy to obtain. After obtaining my dental degree, I took a PhD in forensic medicine with a specialization in forensic odontology. The program, based at the University of Helsinki and University of Tartu, included a set of courses in forensic pathology, death investigation skills, causes of death, and other fields in addition to the dental forensic science. The dental forensic sciences studied included dental anthropology, embryology, and dental development. I also attended special seminars and courses, such as those offered by the United States Armed Forces Institute of Pathology in Maryland and the Karolinska Institute in Sweden. To some degree, forensic odontologists must often put together their own curriculum by combining courses and materials from different institutions. The aspiring forensic odontologist is also well advised to join the

American Academy of Forensic Sciences' Odontology Section and participate at the annual meetings and continuing education activities.

Of course, the very first step to become a forensic odontologist is to go to dental school and become a qualified dentist. Many forensic odontologists are part-time clinical dentists and, even if they eventually give up clinical practice, they will still need to have excellent clinical knowledge. Subsequent training may involve a formal program, but at a minimum has to include investigative skills and a thorough grounding in forensic pathology. The best way to achieve the investigation skills is to work on an active, multidisciplinary forensic team. Being involved in actual case work and training with criminalists, police investigators, and medical examiners is an essential activity. Because no forensic case is routine, the odontologist must be trained to a very high standard. In many cases someone's life is at stake when a forensic examination is performed: a suspect may be convicted or exonerated depending on the forensic evidence. For example, if the suspect's teeth could not have left the bite mark that was observed on the victim's skin, then the suspect could be exonerated. Likewise, based on neonatal line analysis, the forensic odontologist may find that a baby whose body was found discarded was in fact a murder victim, not an unfortunate stillbirth. Small and seemingly unimportant pieces of evidence are almost always worth investigating and so the forensic odontologist must be patient and painstaking in her work. Sometimes, as the first case in this chapter has indicated, even a small tooth fragment can provide the missing piece that unlocks a forensic puzzle.

The next step in becoming a forensic odontologist is to gain an advanced degree if possible and to pursue board eligibility in forensic odontology. As indicated previously, very few advanced degree programs are available. However, there are a number of continuing education courses and short courses that can prepare a forensic odontologist short of a full doctoral degree. For example, the laboratory of Dr. David Senn at the University of Texas at San Antonio offers several such courses. The American Board of Forensic Odontologists does board certification. However, the certification standard is very rigorous and maintaining currency is difficult for forensic odontologists who are not full time. This may explain why only a minority of forensic odontologists actually achieve board certification through the American Board of Forensic Odontologists. One recent study found that highly trained (not necessarily board certified, however), as opposed to medium- and low-trained forensic odontologists, achieved significantly higher identification accuracy *(18)*. This finding strongly emphasizes the critical role of training and recurrent education for forensic odontologists. One cannot emphasize enough how important it is to join a recognized, multidisciplinary forensic team to acquire this training and experience.

8. CONCLUSIONS

Forensic odontology is an exciting field that can combine one's interests in clinical dentistry and criminal investigation. In this exciting field, forensic odontologists may often have the chance to "pull the rabbit out of the hat" and supply the missing piece to a forensic puzzle by means of their detailed knowledge of dentistry, forensic medicine, and criminal investigation.

Forensic odontologists start as highly trained clinical dentists, familiar with tooth development, oral anatomy, disease pathology, and dental surgery and restoration. They combine this specialized clinical knowledge with additional criminal investigative skills in such areas as evidence recovery, documentation, and analysis. This unique combination of clinical and forensic skills makes them uniquely skilled to investigate criminal cases when dental evidence is relevant. Most forensic odontologists participate as part of a wider multidisciplinary forensic team that includes criminalists, police officers, forensic pathologists, and other specialists. Legal cases may quite often turn to the evidence that forensic odontologists are able to interpret. Forensic odontologists often investigate questions of identity in single cases, determine the age of unknown persons living and dead, and analyze facial and dental injury patterns. They almost always play a critical role in mass disaster victim identification, such as the September 11th tragedy. They even play essential roles in purely scientific work, such as forensic anthropology and archeology.

Someone who wants to become a forensic odontologist must first successfully complete dental school and then combine their clinical qualifications with an interest in forensic and criminal matters. Additional training required beyond dental school may consist of attending short-term courses or obtaining an advanced degree in forensic medicine. Most important, the forensic odontologist should join and actively participate in a multidisciplinary forensic team. This teamwork helps to train and keep the forensic odontologist sharp. In this exciting field, forensic odontologists often have the chance to supply the crucial missing piece of a criminal or forensic puzzle that has eluded others.

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Glossary

Antemortem:	Before death. Latin *ante* = before, *mortem* = death.
Anthropology:	The scientific study of the origin, the behavior, and the physical, social, and cultural development of humans.
Archaeology:	The systematic study of past human life and culture by the recovery and examination of remaining material evidence, such as graves, buildings, tools, and pottery.
BCE:	Before Common Era. Years are designated as before the Christ's birth.
Cementum:	A bonelike substance covering the root of a tooth.
Decomposed:	Broken down or disintegrated by rot.
Dentine:	The main, calcareous part of a tooth, beneath the enamel and surrounding the pulp chamber and root canals.
DVI:	Disaster victim identification.
Enamel:	The hard, calcareous substance covering the exposed portion of a tooth. It is the hardest substance of the human body.
Embryology:	The branch of biology that deals with the formation, early growth, and development of living organisms.
Hypoplasia:	A condition of arrested development in which an organ or part remains below the normal size or in an immature state.
Interpol:	International Criminal Police Organization. Interpol has 182 member countries and its headquarters are in Lyon, France.
Molar:	A tooth with a broad crown used to grind food, located behind the premolars.
Neonatal:	Relates to newborn infants.
Odontology:	A science dealing with the teeth, their structure and development, and their diseases. Greek *donti* = tooth.
Orthodontics:	The dental specialty and practice of preventing and correcting irregularities of the teeth, as by the use of braces.
Perimortem:	Around the time of death.
Periodontal disease:	A disease that attacks the gum and bone around the teeth.
Porcelain veneer:	Porcelain coating bonded to the surface of a cosmetically imperfect tooth.

Postmortem: After death. Latin *post* = after, *mortem* = death.

Pulp: The soft tissue forming the inner structure of a tooth and containing nerves and blood vessels.

X-ray: A relatively high-energy photon with wavelength in the approximate range from 0.01 to 10 nanometers. A stream of such photons is used for their penetrating power in radiography, radiology, radiotherapy, and scientific research. Also called roentgen ray.

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