

Forensic odontology – broader than just identification

Richard Bassed¹

Nowadays, most people will associate forensic dentistry primarily with identification and bite mark analysis. These areas do indeed form the majority of an odontologist's workload. There are, however, other aspects of the discipline that are just as important but perhaps less well known. These include cranio-facial trauma analysis, age estimation for both living and deceased individuals, dental manifestations of child abuse, dental malpractice investigations, as well as dental insurance fraud.

Forensic odontology is an integral part of the medico-legal process. With this comes a responsibility borne by forensic odontology practitioners for the requisite education, qualifications and ongoing training. Courts and legal institutions now require that we have evidence-based research upon which we can rest our findings and conclusions. In addition to knowledge of the law, we have to have knowledge of human anatomy and its relationship to injury patterns and interpretation. Knowledge of bite mark patterns due to assault, trauma and sexual abuse, as well as child abuse injury manifestations, is also required, as is knowledge of assessment techniques used when the age of an individual is unknown. Finally, there is a need to have knowledge of human identification methods, principles and practices, as well as mass disaster identification procedures and protocols, and the ethical issues involved in the examination and management of dead bodies, and to have an understanding of human rights issues involved in war crimes investigations.

All of these require thorough knowledge of cranio-facial anatomy, dental anatomy, dental and skeletal development, injury interpretation and medico-legal report writing. It is also important to have a good understanding of the law relating to the practice of dentistry, the coronial system, and the criminal justice system. As the majority of the forensic odontology caseload concerns the identification of unknown deceased individuals, most discussion in this article will concentrate on this.

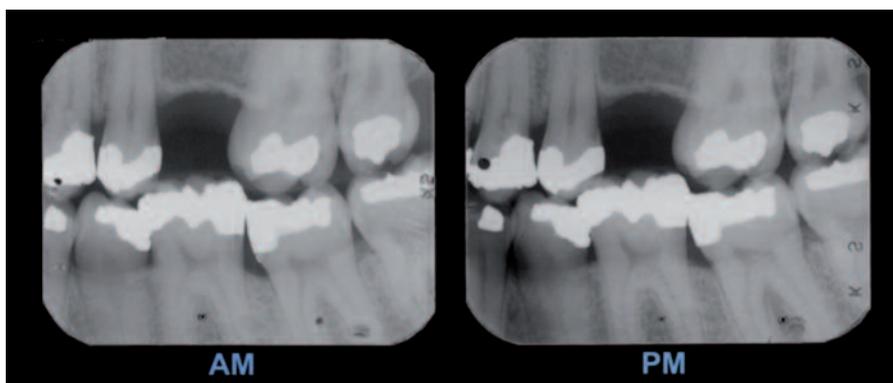


Figure 1: Comparison of ante-mortem (AM) and post-mortem (PM) radiographs, leading to a positive identification.

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Honouring the dead is a fundamental precept in all societies. The extent of this communal attention to the deceased varies across the world, but in essence every person hopes that his or her remains will be treated with respect after death. This respect for the dead includes, for many societies, robust identification of the deceased so that relatives and friends are able to treat the remains with appropriate ceremony and are able to visit the resting place of the deceased whenever they wish. So important is the perception of personal identification in almost all societies that authorities will go to extraordinary lengths to ensure that deceased individuals are not interred in unmarked graves, or cremated without a name.

To be buried anonymously goes against all of our religious, cultural and ethical belief systems, and implies that a life unremembered and unmourned was really a life without consequence. William Gladstone, Prime Minister of Britain in the mid-1800s, encapsulated this sentiment better than most when he said, "Show me the manner in which a nation cares for its dead and I will measure with mathematical exactness the tender mercies of its people, their loyalty to high ideals, and their regard for the laws of the land."

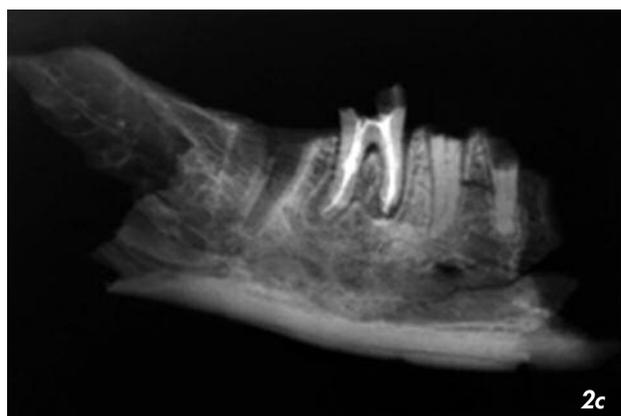
Hal Hallenstein, the Victorian State Coroner from 1986 to 1994, also had firm views concerning the importance of human identification, articulated in the following quotation: "It is a hallmark of our civilisation that we regard it as an affront, an indignity, an abrogation of our responsibilities, that a person could live amongst us, die and be buried without a name." In fact, the importance of identification of the deceased is enshrined in the Victorian Coroners Act 2008 (Section 67), which states "A coroner investigating a death must find, if possible, the identity of the deceased, the cause of death, and the circumstances in which the death occurred."



Figures 2a–c: A more difficult case highlighting that sometimes a degree of interpretation is required.

Positive identification of the deceased not only satisfies a commitment to probity, but also resolves many legal issues surrounding an individual's death, such as inheritance and life insurance. If a deceased person remains unidentified, then technically he or she will not be declared dead for a number of years, thus creating further distress to families who not only are unable to put their lost loved one to rest, but may suffer financially as well.

Personal identification of the deceased, and occasionally the living, is achieved through a variety of scientific and sometimes unscientific methods. Practitioners from forensic science, forensic medicine, law enforcement and coroners' offices apply their own particular set of skills to an identification problem in order to arrive at an answer. The most common method used to identify the deceased in all jurisdictions is undoubtedly visual recognition by a relative or close friend. There is continual debate concerning the veracity of this method, given the propensity for error, which has been well documented, especially in mass casualty



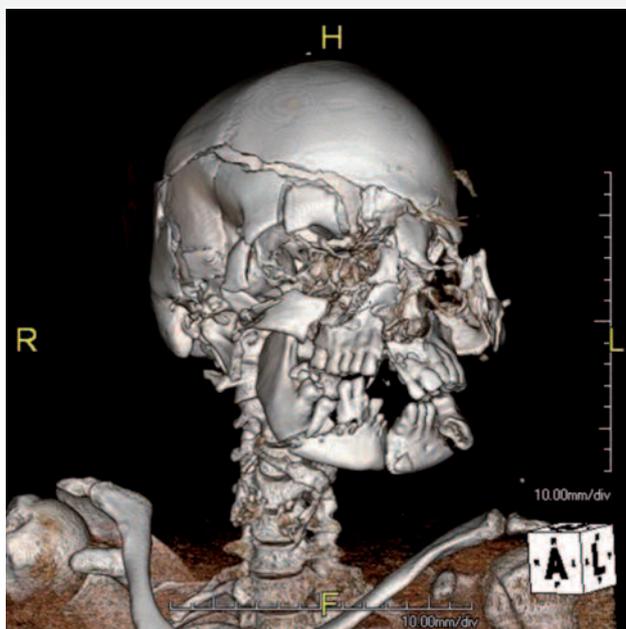


Figure 3: An example of cranio-facial trauma in a homicide case. Accurate injury description can be vital in these cases.

events and in situations in which the deceased has suffered trauma to the face. From the forensic medical/scientific perspective, visual recognition is not proof of identity, but is only presumptive.

Theory of human identification

Methods used to achieve positive human identification can be separated into two broad categories. The first consists of those methods that are presumptive for identification, such as circumstantial evidence, property associated with the body, and visual recognition. These methods involve a high degree of subjectivity and rely on identifiers that are not intrinsic to the body itself, are dependent on lay interpretation, and therefore can be falsified or mistaken (commonly known as secondary identifiers). The second category relies on scientific analysis of identifiers that are intrinsic to the body, such as dental restorations, fingerprints, DNA, and verifiable medical records (primary identifiers). These involve characteristics that can be objectively appraised and compared to ante-mortem exemplars in both a quantitative and a qualitative way and that are difficult or impossible to falsify.

Of all the scientific methods, molecular biology is the only method that can mathematically quantify the degree of certainty for a particular match, with the other methods

(including odontology) being somewhat dependent on more subjective methodology and expert opinion. This reliance on even a small level of subjectivity can raise issues in courts when lay people do not have a deep understanding of the methods employed in an expert's conclusion.

Confusion can arise from the fact that there is often no unanimous indication regarding which and how many characteristics are necessary in order to achieve a positive identification. The recurrence of discordant features excludes identity; the occurrence of several concordant features commonly observed within the population does not allow a final judgment on identification, whereas even a few features rarely observed can lead to a positive match. An example of this is a case in which the written dental chart describes amalgam restorations in each first molar. If the same is found in the deceased, is this sufficient evidence to confirm identity? Definitely not, as many people share this restoration pattern. If, however, we also have ante-mortem radiographs of those restorations displaying the exact shape, size and location within each tooth, and these compare favourably with the post-mortem radiographs, then few would argue that a positive match cannot be confirmed. There is, however, still no way to quantify this match, to put a probability ratio or a percentage certainty to it.

It may be necessary in some cases to compare all of the teeth in a mouth in order to arrive at a match. In other cases, a single tooth with an unusual or complex restoration may be sufficient. It has long been the wish of identification experts to be able to quantify such matches, but no reliable method has yet been devised and so a degree of expert subjectivity is still required.

Prior to the availability of scientific methods applicable to the issue of positive human identification, the only real option for relatives and friends to recover the mortal remains of their loved ones was to visually examine them, and make a decision regarding whether the person before them was indeed who they believed him or her to be. On the face of it, positive human identification by visual recognition would seem to be a fairly simple matter, as long as the deceased has undamaged facial features. We can all recognise people who are well known to us by their facial features and mannerisms, even in poor light and at odd angulations. This has been shown to be true in many studies concerning the recognition of living people via CCTV security footage. Why then are there documented cases of misidentification through visual recognition of the deceased, even of intact and undamaged faces?

The process of visual recognition is complex and until quite

the context in which the individual is seen.

A deceased person has lost all facial expression, animation, and context and simply looks different from when he or she was alive. Incipient decomposition changes may also be present and go unrecognised. Couple this with the stress and trauma being experienced by the identifier, who may well have never seen a dead body before, and it is easy to see how someone may make a mistake. This is compounded by the way visual identifications are often performed, in that the deceased is presented to the identifier to confirm what the authorities already believe they know.

Identification methods

Visual recognition, despite the lack of scientific validity and the propensity for error, will for all practical purposes remain as a major method for positive human identification. When it is determined that visual recognition is not an option, usually because of trauma, incineration, decomposition, or multiple deaths resulting from a single incident, then forensic practitioners are able to rely on more scientific means to determine identity. The common methods employed include molecular biology, medical record comparison, fingerprints, and dental record comparison.

DNA profiles are encrypted sets of numbers that reflect a person's DNA make-up, which can also be used as the person's identifier. Although 99.9% of human DNA sequences are the same in every person, enough of the DNA is different to distinguish one individual from another, unless they are monozygotic twins. DNA profiling uses repetitive sequences that are highly variable, called variable number tandem repeats (VNTRs), particularly short tandem repeats. VNTR loci are very similar in closely related humans, but so variable that unrelated individuals are extremely unlikely to have the same VNTRs. In situations in which a full nuclear DNA profile is not attainable, for example in ancient or degraded remains, mitochondrial DNA analysis may be used, although with less certainty. Identification using DNA evidence relies on the comparison of an ante-mortem sample (reference sample) with a post-mortem sample, and may include direct comparison of the decedent's DNA (e.g. Guthrie cards or an ante-mortem blood sample), or a comparison with relatives' DNA (parents, children or siblings), to arrive at a conclusion. The conclusions of molecular biologists are expressed as a probability ratio and



Figure 4: Age estimation using a standard atlas of development results in an age range that can either lead to identification or help police in limiting their search criteria for a missing person in the case of discovered unknown remains.

are thus scientifically quantifiable as to the strength of the match. With any DNA technique, the cautious juror should not convict on genetic fingerprint evidence alone if other factors raise doubt. Contamination with other evidence (secondary transfer) is a key source of incorrect DNA profiles, and raising doubts as to whether a sample has been adulterated is a favourite defence technique.

Identification using fingerprints (friction ridges) relies on an examination of ante-mortem prints already on file with authorities (exemplars), or more commonly comparison with latent prints retrieved from an object the subject of the examination was known to have touched. Fingerprint identification involves an expert, or an expert computer system operating under threshold scoring rules, determining whether two friction ridge impressions are likely to have originated from the same finger or palm (or toe or sole). The validity of forensic fingerprint evidence has been challenged by academics, judges and the media. While fingerprint identification was an improvement on earlier anthropometric systems, the subjective nature of matching (especially when incomplete latent prints are used), despite a very low error rate, has introduced an element of controversy.

Medical record comparison can be used for identification purposes when there is sufficient ante-mortem evidence of unique medical intervention or disease. Examples include the



Figures 5a–c: Multiple development sites used for age estimation of late teenage individuals: in this case, the third molar, the medial clavicular epiphysis, and the speno-occipital synchondrosis, all of which are useful age indicators in the late teenage years.

discovery of medical prostheses, such as pacemakers and prosthetic hips, which will have engraved on them serial numbers, which can then be reconciled with ante-mortem surgical notes.

Dental identification

When good quality ante-mortem dental records are available for comparison with post-mortem examination findings, positive identification is a relatively simple matter (Figs. 1a & b). For many cases, however, such a simple resolution is not so easily achieved. Often ante-mortem dental records are incomplete or many years old or there are no radiographs. Couple this with incomplete remains or remains damaged by fire and/or trauma and the difficulties are magnified (Figs. 2a–c). Reproducing the exact angulation and aspect of an ante-mortem radiograph in a post-mortem radiograph, taken in less than ideal circumstances, can also be challenging. In order to reach conclusions to these difficult identification puzzles, the forensic dentist not only needs a solid grounding in all of the techniques available, but also requires a level of experience and, in the early years, a degree of mentoring.

Dental identification is not only achieved using comparison

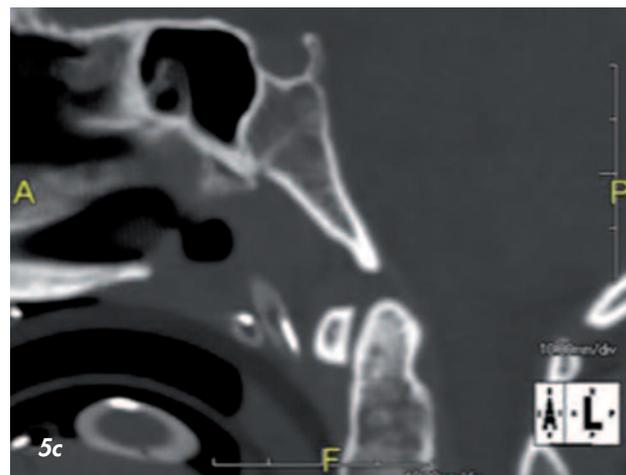
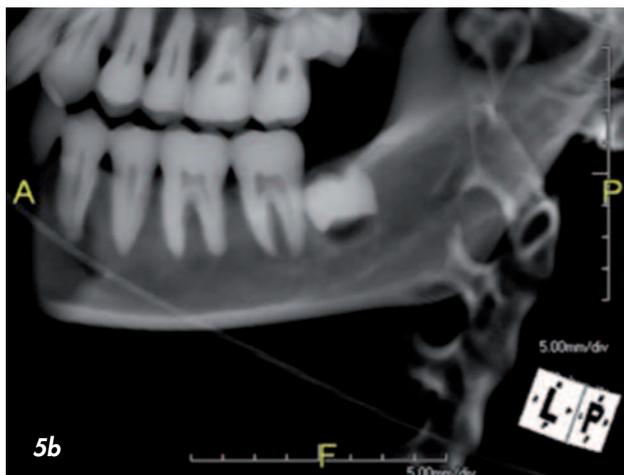
of restorations; other features of the teeth and maxillofacial skeleton may also be employed. Root morphology, sinus configuration, unusual crown shape, and pulp chamber morphology are all factors that can be considered in the absence of restorations, as long as there are high-quality ante-mortem images with which to make a comparison. Study models, sport mouth guards, partial dentures, orthodontic appliances and photographs of the dentition are all useful aids for a forensic odontologist and are employed with varying degrees of certainty, depending on the circumstances of the case.

Personal identification via dental record comparison is similar to fingerprint analysis in that there is, as discussed above, an element of subjectivity involved in the matching process. Where dental identification differs, and is perhaps easier to comprehend for lay people, is in the nature of the evidence being compared. With dental evidence, matches are commonly assessed by comparing both ante-mortem and post-mortem radiographs of easily identifiable man-made (and most often handmade) restorations. Unlike the minute nature of the whorls and swirls of fingerprint evidence, dental radiograph comparisons are often so obviously similar that any reasonable person is able to say that the images belong to the same person.

Other aspects

Aside from identification case work, odontologists are asked to provide medico-legal opinions on a variety of topics as outlined in the introduction. Bite mark interpretation is probably the most recognisable of these to the lay audience and involves the assessment of injuries to the skin that are suspected of being caused by human teeth. This area of forensic practice is fraught with difficulty, as the highly subjective nature of the conclusions reached is almost completely based upon opinion rather than scientific research. There are so many problems associated with the interpretation of bite marks that to describe them all here is beyond the scope of this introductory article.

Cranio-facial trauma analysis is a growing area of forensic odontology practice, and involves examination of both living and deceased individuals and the provision of opinions concerning accurate anatomical description of the injuries (Fig. 3), degree of force (mild, moderate severe), and direction of force application. Occasionally, opinions are also sought regarding the exact nature of the weapon used, although caution needs to be exercised in this regard, as unless the implement bears unique characteristics that are imparted to the body interpretation will be very difficult. This



area of odontology practice predicated a thorough knowledge of cranio-facial anatomy, the biomechanics of bone, and the effect on anatomical structures of various degrees of force.

Age estimation has always been a function of the forensic odontologist, and traditionally has been based upon interpretation of dental development and comparison with published standards for tooth development (Fig. 4). The majority of age estimation work has concentrated on the ageing of children up to 15 years. Beyond this age, dental development becomes relatively unreliable, as only the third molar is available for assessment, and this tooth is notoriously variable in its development. It has been recognised recently, however, that published standards for tooth development may not be as accurate as assumed, owing to the fact that they were constructed many decades ago and in other parts of the world, and therefore may bear little resemblance to modern populations. Considerable work is currently underway to address this issue, with new population datasets being established around the world.

Odontologists are also researching the ability to estimate more accurately the age of older individuals, around the adult/child demarcation age of 18 years. This is being achieved through the use of multifactorial approaches, where the third molar and various other skeletal development sites are assessed together in order to arrive at an estimate (Figs. 5a–c). This is seen as important research in light of the

increasing need to determine the legal status of individuals such as asylum seekers, accused human traffickers who may be children and risk being incarcerated in an adult prison, child soldiers, and victims of sexual assault in developing countries, all of whom are unlikely to possess proof of age documentation.

It has been shown that more than half of all cases of child abuse involve cranio-facial injuries, perhaps owing in part to the significance of the face and mouth in communication and nutrition. Forensic odontologists are rarely involved in these difficult cases, but despite this play an important role in injury description and providing help with determination of causation. All of the principles involved in cranio-facial trauma analysis for adults are applicable here, but with emphasis on the developing anatomy and different biomechanical characteristics of the child facial skeleton.

Dental malpractice and insurance fraud investigations are increasing, partly owing to greater public awareness of what constitutes a dentist's duty of care and responsibility to patients, and partly owing to our increasingly litigious society. For this aspect of practice, the odontologist requires thorough knowledge of the various pieces of legislation relating to dental practice, the professional codes of conduct, and the latest information on treatment modalities, as well as good medico-legal report writing skills.

Conclusion

Forensic odontology is capable of providing rapid and relatively cost-effective identification of the deceased, as long as reasonable ante-mortem dental records are available. In countries such as Australia, the laws concerning medical record-keeping ensure that dental records are, in the main, of good quality and easily retrieved in the event they are required.

In other countries, this may not be the case, and identification of the deceased in some parts of the world represents a serious and ongoing issue for governments and humanitarian organisations. Good record-keeping is not only of benefit to forensic practitioners, but also relevant to improved health services and outcomes for patients in general, so part of the work of odontologists includes educating health authorities in less developed parts of the world to encourage good record-keeping. The benefit of good record-keeping can be seen in recent mass fatality incidents, such as the Victorian Black Saturday bushfires, where, despite the availability of a well-resourced DNA

capability, more than half of all victims were identified by dental record comparison.

The scope of forensic odontology is broader than identification alone and encompasses a range of activities, anything in fact where the practice and theory of dentistry intersect the law. To be a competent practitioner in this discipline requires not only a comprehensive understanding of odontology theory and technique, but also a degree of knowledge and experience in a variety of forensic fields, including law, pathology, clinical forensic medicine, molecular biology and anthropology. The forensic odontologist encounters all of these disciplines in different case scenarios, and in order to understand how the odontologist can contribute best to an investigation he or she needs to comprehend the capabilities and limitations of these fields.

Editorial note: A list of references is available from the publisher.

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