Dental Research Journal

Review Article

Role of forensic odontologist in post mortem person identification

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Received: July 2011
Accepted: May 2012

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ABSTRACT

The natural teeth are the most durable organs in the bodies of vertebrates, and humankind's understanding of their own past and evolution relies heavily upon remnant dental evidence found as fossils. The use of features unique to the human dentition as an aid to personal identification is widely accepted within the forensic field. Comparative dental identifications play a major role in identifying the victims of violence, disaster or other mass tragedies. The comparison of ante-mortem and postmortem dental records to determine human identity has long been established. Indeed, it is still a major identification method in criminal investigations, mass disasters, grossly decomposed or traumatized bodies, and in other situations where visual identification is neither possible nor desirable. This article has comprehensively described some of the methods, and additional factors aiding in postmortem person identification.

Key Words: Barr bodies, fossils, identification, lifestyle, odontometric

INTRODUCTION

Forensic Odontology, or forensic dentistry was defined by Keiser-Neilson in 1970[1] as "that branch of forensic medicine which in the interest of justice deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of the dental findings."Forensic Odontology is an important component of modern day investigations for the identification of people in mass disasters, accidents, or where the victim's bodies cannot be recognized by visual methods. The natural teeth are the most durable organs in the bodies of vertebrates, and humankind's understanding of their own past and evolution relies heavily upon remnant dental evidence found as fossils.[2]

The use of teeth as evidence is not recent. There are historical reports of identification by recognizing specific dental features as early as 49A.C. However, Forensic Odontology, as ascience, did not appear before 1897 when Dr. Oscar Amoedo wrote his doctoral thesis entitled "L' Art Dentaire en Medecine Legale" describing the utility of dentistry in forensic medicine with particular emphasis on identification.[3]

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Historical review

The use of features unique to the human dentition as an aid to personal identification is widely accepted within the forensic field.Identification by dental means is not a new technique. It has been said that Nero's mistress, Sabina, in 66 A.D., satisfied herself that the head presented to her on a platter was Nero's wife as she was able to recognize a black anterior tooth.[4] The modern forensic case started in 1897 in disaster victim identification in Paris by a general dentist. Folklore also ascribes the first use of bite mark identification to King William the Conquer, circa 1066 A.D. whose habit it was to secure his mail with sealing wax imprinted with bite. His anterior teeth were mal-aligned thus allowing verification of authenticity of his documents.[5]

Identification is based on comparison between known characteristics of a missing individual (termed *ante-*

mortem data) with recovered characteristics from an unknown body (termed *post-mortem* data). Many people are familiar with the concept of dental identification; it is frequently mentioned on media. But the nuances and complexities of the process are rarely understood. The central dogma of dental identification is that postmortem dental remains can be compared with antemortem dental records, including written notes, study casts, radiographs, etc. to confirm identity. Clearly, individuals with numerous and complex dental treatments are often easier to identify than those individuals with little or no restorative treatment. The teeth not only represent a suitable repository for such unique and identifying features, they also survive most postmortem events that can disrupt or change other body tissues.[6] Visual identification in those circumstances is subject to error. Methods of human identification that are acknowledged as scientific are fingerprint, DNA, dental and medical characteristics.[2] These methods vary in complexity, but share similar level of certainty. The dental characteristics method is unique in being the easiest and quickest method of identification. The diversity of dental characteristics is wide, making each dentition unique.[3] Dental enamel is the hardest tissue in the body, and would thus withstand peri and post-mortem damages, and so would dental materials adjoined to teeth. Being diverse and resistant to environmental challenges, teeth are considered excellent post-mortem material for identification with enough concordant points to make a meaningful comparison.

Comparative dental identification

Comparative Dental identifications play a major role in identifying the victims of violence, disaster or other mass tragedies. The classic comparative dental identification makes use of both post-mortem and ante-mortem dental records to determine similarities and exclude discrepancies. In many cases the tentative identification of the individual is unknown and therefore ante-mortem records cannot be located. In such cases a dental profile of the individual is developed to aid the search for the individual's identity. With such a profile a forensic odontologist can identify and report indicators for age at time of death, race and sex. In addition to these parameters the forensic dentist may be able to give more insight into the individual. This article outlines for the non-expert, some of the additional personal information that can be derived from the teeth of the deceased, and which may assist in their ultimate identification.

The comparison of ante-mortem and postmortem dental records to determine human identity has long been established. Indeed, it is still a major identification method in criminal investigations, mass disasters, grossly decomposed or traumatized bodies, and in other situations where visual identification is neither possible nor desirable.[7] Dental identifications are expeditious, accurate and cost effective. Despite the well-reviewed nature of comparative identifications, postmortem dental profiles have been somewhat neglected in the forensic literature.[7-10]

Postmortem dental profiles are employed when the tentative identity of an individual is not available and therefore ante-mortem records cannot be sourced. Such situations are not uncommon when remains are skeletal, grossly decomposed or are found naked in locations unrelated to their place of residence. The purpose of the postmortem profile is to provide information to investigators that will restrict the search to a smaller population of individuals. Forensic odontologists can usually determine the sex, race and age (at the time of death) from careful study of the teeth, their anatomical arrangement and the skull's osteological features. They can also extract more information from the teeth of the deceased depending on the habits, professional occupation and other criteria that bring about certain anatomical and constitutional changes in the teeth.

The different methods employed in forensic dentistry include anthropology, rugoscopy, cheiloscopy, bite mark analysis, tooth prints, dental DNA analysis, radiographs, etc.

Forensic anthroplogy

Forensic anthropology plays a vital role in medicolegal investigations of death. Today, forensic anthropologists are intimately involved in many aspects of these investigations; they may participate in search and recovery efforts, develop a biological profile, identify and document trauma, determine postmortem interval, and offer expert witness courtroom testimony.[11] The role of the physical anthropologist is to describe biological variation andexplain it in terms of adaptation, evolution, and history. As teeth are understrong genetic control and are also the only hard part of the skeleton directlyexposed to the environment, this variation takes different forms. Genetic information is sought in the size, shape, and morphologyof teeth, along with numerical deviations away from a species'

dental formula. Dental anthropologists are concerned with genetic and environmental variation provided by teeth, which are the objects of study. Homo sapiens, or recentand modern humans, are the primary focus of dental anthropologists. However, dental anthropologists also study fossil ancestors back to the point of hominidorigins and beyond – to fossil and living primates. As teeth are extremely hard and durable, it is not surprising that they make upa significant portion of the fossil record. This is certainly as true for hominidfossils as for any other tooth-bearing lineage.[12]

Rugoscopy

The study of palate in general is called as Palatoscopy and the study of the patterns of the grooves and ridges (rugae) of the palate to identify individual patterns is called as Rugoscopy. Palatal rugae comprise about three to seven ridges radiating out tangentially from the incisive papilla. Venegas *et al.*[13] determined the shape, size, number and position of the palatal rugae. The most prevalent palatal rugae shape was sinuous followed by curve, line, point and polymorphic varieties. The palatal rugae that were larger were the sinuous. The pattern of these rugae is considered unique to an individual and can be used as reliable method in postmortem cases. The shortcomings in applying rugoscopy as a definitive tool in forensic odontology are many. Postmortem identification is not possible without the antemortem records. To give rugoscopy such importance, previous recording, scanning and preservation through dental casts and computer records are essential. Kapali *et al.*[14] have observed that denture wear, tooth malposition, and palatal pathology can cause alterations in rugae patterns. Thomas and kotz[15] from their studies concluded that different patterns of rugae are genetically determined, and so can be rather used in population differentiation than individual identification. Palatal rugae are often destroyed in fire accident cases and in those cases of decomposition and thus rugoscopy does not have application after this stipulated period.[16]

Lip prints (cheiloscopy)

Lip prints are normal lines and fissures in the form of wrinkles and grooves present in the zone of transition of human lip, between the inner labial mucosa and outer skin, examination of which is known as cheiloscopy.[17] Lip prints are unique for individuals like the finger prints. Lip print recording is helpful in forensic investigation that deals with identification of humans, based on lip traces. A lip print may be revealed as a surface with visible elements of lines representing the furrows. This characteristic pattern helps to identify the individuals since it is unique for individuals. One common problem that is encountered during the cheiloscopic studies is that of smudging or spoiling of lip prints leading to unidentifiable marks When the lines are not clear (Only the shape of lines is printed), individual identification of human being based on this trace is extremely difficult, unless the trace contains more individual characteristics like scars, clefts etc, and often identification ends with group identification.[18,19]

Bite mark analysis

The science of identification of bite mark identification can be used to link a suspect to a crime. Bite can be defined as the mark made by human or animal teeth in the skin of alive people, cadavers or unanimated objects with relatively softened consistency.[20] Bite marks depending upon the crime or circumstances are impressions left on food, skin or other items left at a scene. In assault cases they may be found on the victim. Besides the agent identification, bite mark analysis, in a forensic investigation, can elucidate the kind of violence and the elapsed time between its production and the examination. It can show if the bite was produced intra-vitam or post-mortem and in case of several bite marks, identify their sequence.[20] The identification of the perpetrator can also be done by the determination of ABO blood groups from the saliva on the bite mark, and linking bacteria and other microorganisms found in the bite mark to the oral milieu of the perpetrator. Newer techniques that have enhanced bite mark identification include application of electron microscopy and computer enhancement technique. However, bite marks do not embody all the requisites of an ideal identification method (unicity, immutability, practicability, classifiability), but it can represent in some cases, the unique signs of real value to criminal investigation.[21] There are many drawbacks of bite mark analysis. The size of the bitemark may shrink in size in a relatively short duration (10-20 minutes) and this necessitates their recording at the earliest possible time.[17] Incomplete bite marks are not conclusive and a minimum of four to five teeth have to be present for reliable bite mark analysis.

Forensic radiology

The situations in which forensic radiology can be applied to resolve legal matters are many and varied.

The importance of radiographic techniques in clinical forensic medicine is widely recognized. It is common practice to obtain radiographs as part of postmortem examinations in order to locate foreign bodies or document fractures or other injuries.[22] The stage at which radiology is implemented during autopsy varies according to the individual circumstances, but usually it is after the external examination and prior to the dissection.[23] The utilization of radiographs in identification is valuable if sufficient antemortem records are available. Various morphological and pathological alterations can be studied from the radiographs. Crown and root morphology aids in identification. The presence of decayed, missed, filled, and fractured teeth, various stages of wound healing in extraction sockets, degree of root formation, and bone trabecular pattern in the jaws aid in identification.

DNA methods

Dental structures are relatively more resistant to higher temperatures. Techniques involving DNA in Forensic Dentistry offers a new tool when traditional identification methods fail due to the effects of heat, traumatism or autolytic processes, as well as in distortions and difficulties in analysis.[24] They can provide a source of DNA for easy identification. Due to this abundance of material, the use of the technique based on PCR (Polymerase Chain Reaction) has acquired great importance in DNA post-mortem analysis in forensic cases. Polymerase Chain Reaction is an enzymatic amplification of a specific DNA sequence, aiming millions of copies production from this sequence in a test tube, which was first described by Kary Mullis, in the late 1980's, and enabling a new strategy of gene analysis though a simple and fast method, excusing all the laborious stages of genic cloning.[24] The method using PCR enables the distinction of a subject among the other ones with a high level of reliability, starting by 1ng (nanogram), equivalent to a single part in a billion grams, of the DNA target.[25] Saliva is a very useful DNA source due to the fact of being collected by painless and non-evasive way, able to be used even when it is stored in the most different conditions.[26] However, the molecular methods are relatively new and need to be evaluated different methods of identification applicable in forensic dentistry are available. However, each one has its own limitations and this should be kept in mind while applying such techniques. It is necessary to broaden the pertinent studies of the theme in order to establish protocols to allow additional tools in criminal investigation.

Forensic anthropometry

Anthropometric studies are today conducted for numerous different purposes. Academic anthropologists investigate the evolutionary significance of differences in body proportion between populations whose ancestors lived in different environmental settings. Human populations exhibit similar climatic variation patterns to other large-bodied mammals, following Bergmann's rule, which states that individuals in cold climates will tend to be larger than ones in warm climates, and Allen's rule which states that individuals in cold climates will tend to have shorter, stubbier limbs than those in warm climates. Today people are performing anthropometry with three-dimensional scanners. The subject has a three-dimensional scan taken of their body and the anthropometrist extracts measurements from the scan rather than directly from the individual. This is beneficial for the anthropometrist in that they can use this scan to extract any measurement at any time and the individual does not have to wait for each measurement to be taken separately. This method holds importance in investigations involving the use of forensic odontology.

Factors aiding forensic investigation in individual person identification

Occupation anddental considerations

Knowledge of an individual's occupation can assist greatly in the locating of ante-mortem records. Most occupational diseases result in the loss of dental hard tissues or tooth staining. Occupational tooth substance loss can occur due to three main systems – abrasion, erosion and by caries (decay).

Individuals working within dusty or particulate environments will frequently exhibit abrasion of their dental hard tissues. This is caused by the grinding of teeth onto hard, roughened particles within the mouth. Such abrasion is most commonly seen on the biting surfaces of the teeth (occlusal and incisal).[27] Industries such as flour millers, stone grinders and cement workers may in the absence of proper precautionary measures, exhibit such tooth substance loss.[28,29] Such wear may eventually lead to the exposure of dentine and ultimately the pulp complex. Treatments include the provision of adhesive gold onlays (gold which is placed on the tooth to replace the lost tissue) or resin-bonded tooth coloured restorative materials. While it would be impossible to identify the actual particulate causing the abrasion, e.g. cement, stone or flour, the location of a factory of this type in the area of body

discovery may assist the ultimate identification. The list presented in Table 1, includes many of the more common dental diseases or conditions, which can be attributed to the occupation of the individual.

Table 1: Depicts the oral manifestations in the oral cavity due to the occupation of the deceased

Occupation	Dental appearance	Cause
Miners Grinders Stone cutters Saw mill workers Flour mill workers	Generalized abrasion	Abrasive dust formation and collection on the occlusal surfaces of the teeth
Sugar refiners Bakers Candy makers[30]	Caries on the labial and buccal surfaces of the teeth	Sugar dust deposits, and stagnates, buccal surfaces of the teeth
Metal workers: *Copper* *Nickel* *Iron* *Tin*	Green staining of dentition Green staining of dentition Fine black lines on teeth Yellow staining of teeth	Inhalation of dust Inhalation of metal fumes leads to deposition of tin sulphide
Chemical workers: *Citric acid, tartaric acid, hydrochloric acid, sulphuric acid, etc*	Smooth polished eroded surfaces	Decalcification of enamel and dentine, due to exposure to fumes. Main effect to labial surfaces. Mastication and tooth brushing lead to loss of tooth substance
Superphosphate industry: *production of phosphorus and hydrogen peroxide*	Fluorosis	Fluorine compounds used in this industry have a direct effect on ameloblasts, specially in younger workers
Battery factory worker	Yellow, gold-brown staining of labial surfaces and erosion of incisors	Cadmium exposure causes the extrinsic staining while the battery acids are responsible for the erosion
Shoe Upholsterers Glass blowers Dress designers Seamstresses Electricians	Abrasion – single of multiple groves found on incisors between their teeth	Holding nails, takes, needles etc, between their teeth
Wine tasters	Erosion, mainly on the labio-cervical surfaces on maxillary incisors and canines	Wine tasting on a daily basis with at least 20 wines tasted per day. Wine pH varies from 3.0 to 3.6 typically

Medical conditions and treatments

Knowledge of an individual's health status can be an important clue in the determination of identity and can provide another valuable variable to narrow the search for ante-mortem records. Medical records can be searched using keywords relating to a particular disorder or treatment and when combined with other defining characteristics, may enable investigators to provide a tentative identification. Conditions that have a genetic component can be traced using family histories which may in these rare conditions, provide a useful insight to an individual's identity.

The multitude of obscure diseases that can present intra-orally can be narrowed when considering those which impact upon the dental hard tissues. It is likely that in a post-mortem dental profile it is these tissues that will form the basis of the odontologist's examination [Table 2].

Habits and dental appearances

A number of lifestyle habits have an effect on the dental tissues. This can be useful in the search for an individual – information such that the individual was a pipe smoker can facilitate the ante-mortem record search and prompt people who may have known them. Common habits, such as tea and coffee drinking, cause extrinsic stains but due to their high incidence in the population, their use as identifying features may be insignificant. However, other habits offer more useful indicators for investigators. Pipe smoking is a good example of this. Habitually, pipe smokers place the pipe stem in the same location and thus create, over time, a wear pattern in this area. Pipe smoking is also associated with the usual nicotine stains and a range of soft tissue appearances which are beyond the scope of this article. The recognition of smoking stains can also be of use in the placement of a cigarette in an artist's impression [Table 3].

Abnormalities of tooth formation and eruption

There is a range of rare conditions that affect the developing dentition that lead to distinctive hard tissue appearances. These are listed and described in Table 4. The incidence and prevalence levels are low for each condition and therefore they present useful identifying features for investigators. Many of the conditions are associated with severe medical conditions and it is likely that extensive medical and dental records (often in specialist practices) will be available for such individuals. Their unique physical and dental appearances are easily recognizable to

Table 2: Depicts the systemic conditions and their associated dental findings

Medical condition	Appearance (In dentition)	Cause
Hiatus Hernia[31] Gastric ulcer[32,33] Gastro-oesophageal reflux disease (GORD)	Marked erosion of the palatal surfaces of the maxillary incisors and premolars	Regurgitation or vomiting of gastric contents. Gastric acid has a pH below 1.
Anorexia nervosa Anorexia athletica Bulimia nervosa[34,35] Rumination Chronic alcohol abuse	Marked erosion of the palatal surfaces of the maxillary incisors and premolars	Induced vomiting of stomach contents
Neonatal jaundice	Green to yellowish-brown discolouration of the teeth. Enamel hypoplasia may also occur	Most frequently associated with rhesus incompatibility
Congenital porphyria	Affected teeth show a pinkish-brown discoloration that fluoresces red under UV light	Autosomal recessive inheritance. Circulating porphyrins in the blood are deposited in the dental hard tissues
Congenital syphilis[36,37]	Hutchinson's incisors and Mulberry molars – distinctive shaped teeth	Transmission of *Treponemapallidum*from an infected mother
Drugs used in treatments and dental considerations		
Iron supplements	Black staining of teeth	Surface deposition following oral courses
Minocycline[38-40] Chlorhexidine	Brown/black staining	Precipitation of dietary chromogens

Table 3: Depicts the functional and parafunctional habits and their dental effects

Habit	Appearance	Cause
Coffee, tea, red wine drinkers	Brown/black staining on labial,lingual and palatal surfaces	Extrinsic staining
Pipe smoking	Unusual patterns of tooth wear in addition to staining	Wear
Painting (canvas)	Unusual patterns of erosion especially on the buccal surfaces	'Gouache' in paint is acidic, and transferred to mouth as brushes are often placed intra-orally
Betel nut use	Staining on buccalsurfaces,usually unilateral	Extrinsic staining
Cocaine	Localised and severe dental caries, particularly in the maxillary premolar region	Testing the purity of cocaine by rubbing it into the gums. Cocaine is often mixed with sugar
Heroin	High caries rate and severe periodontal disease	Oral neglect
Methadone syrup	Rampant caries	Methadone is often delivered as a sugary syrup which adheres to teeth tenaciously

witnesses, relatives and family members. As many of these conditions have a genetic basis, a family history may be available.[30]

Location of residence anddental considerations

The determination of likely place of residence can be based on the dental techniques, the quality of work and dental materials that have been used to restore the deceased's dentition. An assumption is made that the individual had their dental work performed in their country of residence. It is unlikely that a particular country can be identified; however, geographical areas can be identified. Dental techniques and the materials available to perform them vary widely, and are usually influenced by the affluence of the country. Dental training is also highly variable, and in many countries there is little or no formal dental training.

Two examples are described here. The first example is from Russia. Russian dentistry can often be categorized by the use of non-precious metals faced with acrylic rather than porcelain crowns, the use of non-precious metals in the anterior portion of the dental arch and work of a generally lower quality than is seen in the West.

The second example comes from China. In this example the dental work was an indicator that the individual was from or had spent time in Asia. The dental work utilizes only two natural teeth (canines) to provide support for extensive bridgework. The bridgework is acrylic with wooden components and an underlying metal framework. In the West, more likely treatments would have been a removable denture, over-denture or implant supported prostheses.

These two examples serve to illustrate that dental work can be a possible indicator of place of residence. Unusual restorative techniques may alert the investigator to the possibility that the individual may originate from or have spent time in a foreign country. It is important to remember that good and poor quality dental work can be provided in any country. However,

Table 4: Depicts the Tooth abnormalities and their prevalence

Abnormality	Description	Prevalence
Supernumerary teeth	Most common in the premaxilla. 75% do not erupt (visible on postmortem radiographs). May be conical, tuberculate (multi-cusped), supplemental or odontome-like	1.5-3.5% M:F 2:1
Hypodontia[7]	Missing teeth. Effects, in descending order of frequency, mandibular and maxillary 3rd molars (wisdom teeth), mandibular 2nd molars, maxillary lateral incisors, and 2nd premolars. Severe Hypodontia is associated with Down's Syndrome and ectodermal dysplasia	3.5-6.5% M:F 1:4
Macrodontia and Microdontia	Abnormality of tooth size, microdontia mainly affects the maxillary lateral incisors – so called peg laterals. Strongly associated with hypodontia	1.1% (Macro) Overall occurrence 2.5%
Hypoplasia	Enamel defects – usually caused by premature loss of deciduous teeth – can be an indicator of neglect or poor oral care	
Amelogenesisimperfecta[41,42]	Genetic defect with various presentations, either hypoplastic or hypocalcified	Family history good predictor – genetic basis
Dentinogenesisimperfecta[42]	Translucent grey teeth – shell teeth may be present	Uncommon – genetic association – family history

unusual or gross departures from the norm should always be considered as potentially significant.

Sex determination anddentition and dentition

Several authors have examined the ability to determine gender using odontometric analyses. A famous study by Rao *et al.* uses the mandibular canine index to determine sex, although another study has issued a caution in using this technique.[43,44] Another study, using dental casts of children, showed that the teeth, and in particular the canines were larger in males than females, and suggested this method for determining gender in children whose secondary sexual characteristics had not develop.[45] Many researchers believe that measurements of tooth size or assessment of morphology are insufficiently accurate for forensic identification, particularly in light of more objective methods.[46] Two examples of such methods are provided. The first is a microscopic technique in which the pulp tissue is examined for Barr bodies (present only in females). This technique has been shown to be of value in burnt and mummified remains and is highly accurate.[47] The second method is based upon PCR analysis of DNA, sourced from the dental pulp, and the subsequent analysis of the amelogenin gene for sex determination.[1] Though not unique to DNA obtained from dental pulp, the teeth often remain the only source for DNA following incineration or other postmortem events.[4]

CONCLUSIONS

This article has comprehensively described various methods that can be used for post mortem identification as well as the additional postmortem findings which can be determined from the study of individual's teeth. It is implicit that none of these items can lead to a positive identification but when combined with other dental and circumstantial evidence, they can assist in the focusing of a search for ante-mortem records or provide useful information for forensic artists. A forensic dentist carries a considerable responsibility since his scientific opinion is frequently asked when all other paths of identification have been exhausted. There are instances in which teeth are the only preserved human remains and present the only means of identification in order to narrow down the search within the missing person's file and enable a more efficient approach. In these cases final identification may depend on specific odontological matching of pre and post-mortem dental data, DNA-typing and fingerprinting, Anthropometry.

Forensic dentistry plays an important role not only in mass disasters (terrorist attacks, earthquakes, Tsunamis), child/elder/spouse abuse, bite mark analysis, criminal/natural deaths and injuries, bioterriorism etc., but also helps in identification of decomposed and charred bodies like that of drowned persons, burns, and victims of motor vehicle accidents. The various methods have been employed in forensic odontology which include bite mark analysis, tooth

prints, rugoscopy, cheiloscopy, DNA analysis, radiographs,etc., thus aiding in individual identification and thus playing an important role in forensic sciences.

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How to cite this article: Pramod JB, Marya A, Sharma V. Role of forensic odontologist in post mortem person identification. Dent Res J 2012;9:522-30.

Source of Support: Nil. **Conflict of Interest:** None declared.