Review article

Indian Journal of Forensic Odontology
Volume 5 Number 3, July - September 2012

Forensic Odontology: An Overview

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Abstract

Forensic dentistry, from its earliest conception, is more or less an offshoot of forensic medicine, the dental surgeon being consulted only in cases where dental data and details are evident to them. With the passage of time, the role of dentistry has increased as very often teeth and dental restorations are the only means of identification, especially after tragic destructive disasters, accidents, and fires where facial configuration and fingerprints are entirely lost. Teeth, jaw bone, salivary remnants, elements from oral tissues and tissue fluids, presence of foreign bodies, sinus configuration, skull sutures, comparison possibilities from radiographs of small and specific sites of the jaws and teeth, model comparisons, dental chart comparisons, dental treatment comparison, and DNA analysis all provide an enormous wealth of identification characteristics and knowledge. This article gives the readers an understanding of the role of a dentist as a forensic odontologist and also emphasizes the need for good quality and accurate dental records.

Key words: Forensic science; Identification; Odontology; Teeth.

Introduction

The term 'forensic' implies 'court of law'. Forensic odontology has been defined as that branch of dentistry, which, in the interest of justice, deals with the proper handling and examination of dental evidence and with the proper evaluation, and presentation of dental findings. Forensic odontology has played a key role in identification of persons in mass disasters (aviation, earthquakes, Tsunamis), in crime investigation, in ethnic studies, and in identification of decomposed and disfigured bodies like that of drowned persons, fire victims, and victims of motor vehicle accidents. The various methods employed in forensic odontology include rugoscopy, cheiloscopy, bite marks, tooth prints, radiographs, photographic study, and molecular methods. Though the shortcomings with these various methods are few, the discrepancies associated with them are to be weighed cautiously to make forensic odontology a more accurate, reliable, and reproducible investigatory science. In this article, the limitations of various methods employed in forensic odontology are discussed.[1]

There are three major areas of activity currently in forensic odontology namely:

- The examination and evaluation of injuries to teeth, jaws, and oral tissues resulting from various causes (abuse, assault, mass disasters and crime related injuries).

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- The examination of marks with a view to subsequent elimination or possible identification of a suspect as the perpetrator.
- The examination of dental remains (whether fragmentary or complete, and including all types of dental restorations) from unknown persons or bodies with a view to the possible identification of the latter.[2]

Dental identification has played a very important role in natural as well as manmade disasters. 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). When they have no clue of the identity or no ante-mortem records are present, a detailed postmortem record is compiled for further use and a forensic anthropologist is used for contributing information such as age, sex and ancestry of the deceased, which is known as postmortem dental profiling.[3]

An ante-mortem dental record will contain written notes, charts, diagrams, dental and medical histories, radiographs, clinical photographs, study models, results of specific tests, prescriptions, and referral letters and other information. Their accuracy and availability have a huge impact on the speed and efficacy of identification. Problems are encountered when the dental records are incomplete, irregular, lost or damaged and have poor quality radiographs.[4]

Good quality dental records are an essential part of patient care, a medico-legal requirement, and are necessary for dental identification. A forensic dentist records the postmortem records completely by charting down the dental findings and taking photographs and radiographs. On completion a comparison between the two is carried out, similarities and discrepancies are noted on the comparison and a result is established.[5]

Application of forensic odontology in all the disciplines

A working classification is been proposed by Shamim T involving all dental specialties [6]

Periodontics

Age estimation

- Periodontosis (gum recession)
- Root transparency and root length

Identification

- Gingival morphology and pathology
- Thickness and widening of periodontal ligament

Conservative Dentistry

Identification and endodontics

- Restorations
- Endodontic treatment

Identification using radiographic method (Periapical radiograph)

- Root canal treated restorations(
- Radiolucent and radio-opaque restorative materials

Effect of heat on restorative materials.

Orthodontics

Age estimation

- Cephalometrics
- Orthopantomograph (OPG) X-ray and handwrist
- X-ray to determine pubertal state

Identification

- Tooth rotation and malposition
- Orthodontic appliances
- Orthodontic reconstruction

Sexual dimorphism

- Mandibular canine index and mandibular first molar index

Race identification

- Cephalic index

Craniofacial superimposition

Oral and maxillofacial surgery

Identification

- Maxillomandibular and dentoalveolar fractures
- Surgical repairs and implants
- LeFort I osteotomy procedure in autopsy

Oral medicine and Radiology

Age estimation using radiographic method

- Secondary dentin formation
- Changes in the orientation of mental foramen and inferior alveolar canal
- Eruption and formation of mandibular third molar
- Trabecular pattern in jaws
- Pulp/tooth area ratio of teeth
- Pattern of lamina dura

Identification

- Maintenance of dental records
- Dental charting
- Comparative dental identification
- Cheiloscopy

Pedodontics

Age estimation

- Eruption sequence
- Schour and Massler chart
- Demirjian's methods using dental maturation chart
- Nolla's calcification stages
- Child abuse

Oral pathology and microbiology

Age estimation using ground sections (histological method)

- Gustafson's technique
- Incremental lines of Retzius
- Perikymata
- Prenatal and postnatal lie formation
- Racemization of collagen in dentin
- Cemental incremental lines
- Translucency of dentin

Identification

- Developmental disturbances of teeth
- Regressive alterations of teeth
- Tumours and cysts of oral acvity
- DNA profiling from teeth

Community dentistry

Identification

- Endemic fluorosis
- Socioeconomic grouping
- Mass disasters

Dental fraud and malpractice

Elderly abuse

The American Board of Forensic Odontology recommends that these be limited to the following four conclusions.[7]

Insufficient evidence

The available information is insufficient to form the basis for a conclusion.

Exclusion

The ante-mortem and postmortem data are clearly inconsistent

Positive identification

The ante-mortem and postmortem data match in sufficient detail, with no unexplainable discrepancies, to establish that they are from the same individual.

Possible identification

The ante-mortem and postmortem data have consistent features but, because of the

quality of either the postmortem remains or the ante-mortem evidence, it is not possible to establish identity positively.

Dental Profiling

When dental records are unavailable and other methods also become impossible, a picture of the general features of the individual is produced and this is known as post mortem dental profiling which includes information on the age, sex, socioeconomic status and ancestry background of the deceased. Additional information's such as habits, dietary pattern and occupation may also be provided.[8]

Race

Dentists with the help of a forensic anthropologist can determine the sex and ancestry from skull shape and form. A forensic dentist can determine race within the three major groups: Caucasoid, Mongoloid and Negroid based on the skull appearance. Additional characteristics, such as cusps of Carabelli, shovel-shaped incisors and multi-cusped premolars, can also assist in determination of ancestry.[9]

Sex

Sex determination is usually based on cranial appearance, as no sex differences are apparent in the morphology of teeth. Discriminant function analysis, a statistical method used for determination of sex based on tooth measurements showed a success rate of 92.5%.[10]

Minute quantities of DNA even from very old tooth specimens are helpful in determining the sex. Ameloblasts of the enamel secrete amelogenin (AMEL gene) which is present in the X and Y chromosomes of humans, females have two identical AMEL genes (XX) and males have two non identical AMEL genes (XY). Discrimination of male and female is based on the length of the base pairs of the gene which is 106 and 112 for X and Y gene respectively. A sample which shows two discrete bands of 106 and 112 is identified as male and a female sample appears as a single band of 106 for the AMEL gene.[11,12]

Age

Teeth act as a reliable tool in estimation of age. Eruption sequence, neonatal line formation, Incremental lines of Retzius, Schour and Massler chart and Gutafsson's method are parameters used for age estimation.[13]

The use of radiographs is ideal to determine the stages of mineralization, degree of formation of root and crown structures, and stages of eruption which are reliable and helpful in predicting the age of an individual.[14]

Other methods used for identification

Cheiloscopy

The external surface of the lip has numerous elevations and depressions that form a characteristic pattern, referred to as lip prints. Lip prints can be obtained at the crime scene from clothing, cups, glasses, cigarettes, windows, and doors. Using lip prints for personal identification in forensic odontology is an accepted method in the criminal justice system worldwide. Impressions are made from the middle portion of the lower lip, an area always visible in any trace made, and the characteristic patterns are studied. The various patterns identified include vertical, intersected, branched, reticular, and undetermined. The anatomical landmarks of the lip include chelion (the lateral most point in mouth opening), stomion (the contact of upper and lower lips in mid-sagittal plane), and labrale superius and labrale inferius (the highest and lowest points of upper and lower lip margins in the mid-sagittal plane, respectively).

Various factors can alter lip print recording. Lip prints have to be obtained within 24 hours of the time of death to prevent erroneous data that would result from postmortem alterations of lip.[15]

Lip print pattern depends on whether the

mouth is opened or closed. In closed-mouth position lip exhibits well-defined grooves, whereas in open position the grooves are relatively ill defined and difficult to interpret. Any pathology of the lip such as mucocele or any postsurgical alteration of the lip can change the lip print pattern. Also, loss of support due to loss of anterior teeth can cause changes in lip prints. Any debris or fluid on the lip surface, application of a thick layer of lipstick, or over stretching of cellophane tape can alter lip print recording. Although lip prints are unique to an individual, when the lines are not clear, individual identification based on this trace is extremely difficult unless the trace contains more individual characteristics like scars, clefts, etc.[15]

Rugoscopy

Palatal rugae comprise about three to seven ridges radiating out tangentially from the incisive papilla. These ridges can be classified as curved, straight, wavy, and branched. The pattern of these rugae is considered unique to an individual. In instances where postmortem dental identification is not possible, as in edentulous mouths, palatal rugae can be used as a supplement.

The shortcomings in applying rugoscopy as a definitive tool in forensic odontology are many. Postmortem identification is not possible without the antemortem records. Complex rugae patterns (patterns that cannot be classified under one particular group) can cause intra or interobserver errors. Kapali *et al* have observed that denture wear, tooth malposition, and palatal pathology can cause alterations in rugae patterns.[16]

Further, Thomas *et al.* have stated that rugae patterns are genetically determined, and so can be rather used in population differentiation than individual identification.[17]

In a situation involving fire, palatal rugae are often destroyed, and also since decomposition and skeletonization can occur in less than six weeks in summer and four months in winter, rugoscopy does not have application after this stipulated period.[18]

Bite marks

Bite mark is vital evidence in case of crime and abuse and can go unnoticed by untrained individuals. Recording, comparing and determining whether the mark is truly a result of biting is important for a forensic odontologist. Knowledge on the arch alignments and specific tooth morphology of animals is also required for a forensic odontologist to distinguish human bites from non-human.

Bite marks are usually documented taking photographs or taking impressions. Measuring the size of the tooth of the suspect and comparing it with bite mark can be done with metric analysis.

When a good impression of the bite is left behind the physical characteristics like distance from cuspid to cuspid, shape of the arch, evidence of mal-alignment, spacing, teeth width and thickness, missing teeth and wear patterns are taken into consideration for comparing bite mark wound and suspect's teeth.[19]

The drawbacks encountered in recording bite marks are however many. Due to inherent alterations, the shape and clarity of bite marks found on the skin of the victims change in a relatively short duration (10-20 minutes) both in living and dead, and this necessitates their recording at the earliest possible time. Though photographed immediately, the three-dimensional bite marks on the two-dimensional photograph will be associated with changes in color and spatial relations. Also, incomplete bite marks are not conclusive and a minimum of four to five teeth has to be present for reliable bite mark analysis.[20]

Tooth prints (Ameloglyphics)

Ameloblasts lay down the enamel rods in an undulating and intertwining path. This is reflected on the outer surface of the enamel as patterns of the ends of a series of adjacent enamel rods. This study of the enamel rod end

patterns is termed as ameloglyphics by Manjunath *et al.* and could aid as an identification tool in decomposed or burned bodies as enamel can resist decomposition.[21]

This study needs ante-mortem records. Though enamel is the hardest mineralized substance in human body, the enamel surface is usually subjected to micro and macro wearing. Fractured, decayed, attrited, abraded, and eroded teeth cannot be included in this method. Ameloglyphics is still in its infancy and whether the tooth prints are the same at different depths of enamel has to be evaluated with further studies.

Radiographs

Dental features do change over time and for this very reason, dental-based identification is considered less reliable compared to other biometric methods like finger prints. But in victims where there is complete decomposition, radiographs may be the only available biometric method. Various morphological and pathological alterations can be studied from the radiographs. In morphology-based studies, root morphology comparatively aids better in identification than crown morphology.[22]

Apart from routine findings, like 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.

There are difficulties in matching the viewing angles (identical projection, angulation), exposure, and similar magnification in postmortem radiographs to those taken ante-mortem. Also, the state of dental remains may entirely preclude the possibility of taking certain types of postmortem radiographs.

Photographs

Photographs are valuable substitutes for written records and can overcome language barriers. However, photographs have considerable inherent limitations and stringent requirements are needed for accurate reproduction. The basic difficulty arises when three-dimensional objects are replicated as two-dimensional photographs, which can create distortion, and color change. Photographs are sometimes associated with parallax errors. Lighting, camera orientation, close-up capability, and stability are extremely critical factors while taking photographs. Tripod should support the camera perpendicular to the long axis of the object to be photographed. Photographs without a scale or any circular reference devices may be inherently inaccurate. Small plastic rulers are subject to certain extent of inaccuracy and ABFO scale no.2 is designated as a standard scale.[23]

Molecular evidence: Deoxyribonucleic acid (DNA)

Because of the resistant nature of dental tissues to environmental assaults, such as incineration, immersion, trauma, mutilation and decomposition, teeth represent an excellent source of DNA material.[24]

When conventional dental identification methods fail, this biological material can provide the necessary link to prove identity.[25] With the advent of the polymerase chain reaction (PCR), a technique that allows amplification of DNA at pre-selected, specific sites, this source of evidence is becoming increasingly popular with investigators. Comparison of DNA preserved in and extracted from the teeth of an unidentified individual can be made to a known ante-mortem sample (stored blood, hairbrush, clothing, cervical smear, biopsy, etc.) or to a parent or sibling.[26]

Genomic DNA

Genomic DNA is found in the nucleus of each cell and represents the DNA source for allowed criminal investigators to link victims to crime scenes once the body has been removed and incinerated.[27]

Mitochondrial DNA

In addition to genomic DNA, cells contain mitochondrial DNA (mtDNA), the sequence of building blocks of which can be determined to assist in identification. The main advantage of mtDNA is that there is a high copy number in each cell caused by the high number of mitochondria present in most cells. This infers that in cases where genomic DNA cannot be analyzed, possibly because it is too degraded, mtDNA may be present in sufficient quantity. In addition to its higher copy number, mtDNA is maternally inherited.[28]

This maternal inheritance pattern confers the same mtDNA sequence, barring mutations, upon siblings and all their maternal relatives. This has important implications for the identification of individuals for which there is no ante-mortem comparison sample. Although mitochondrial DNA is still in its infancy in forensic casework, it is a powerful technique that is likely to become commonplace in the future.

Newer advances in forensic odontology

3-D Stereophotogrammetry

Originally developed by Faraday Institute university of Glasgow; comprise of twin single lens reflex camera system. The distance between both the eyes is 20 mm from inner canthus. This binocular disparity, when integrated by the visual cortex in the brain, results in a combination of images to create depth and field; the process of fusion being known as "stereopsis". Siebert and Urquhart (1994) developed the C3D models of real objects.[29]

Magnetic resonance imaging (MRI) or Nuclear magnetic resonance (NMR)

Chudek et al (2003) used MRI scan to trace the bitemark trails and stop marks in food items, for forensic purpose. These images can be used, to identify areas of anatomical interest, in order to identify a possible suspect. Example surface lines from fractured areas of enamel, interdental discrepancies. Drawbacks of NMR are the size of the equipment and cost; however the advantages are the overall images and their manipulation to form 3D images, to allow possible positive identification of the individual; without having to make impressions or casts.[30]

Implant based identification

Sewerin 1992 first described and analyzed radiographic images of ten dental implants from different viewing angles. Morphological features of dental implants depicted on radiographs may be used to develop a dental profile of the individual in forensic cases. Nuzzolese et al 2008 archived radiographic images of Italian dental endosseous implants to be employed in forensic caseworks to narrow the investigation of unidentified victims with one or more dental implants. Some implants have perforations, grooves, apical chambers and threads that are visible only at certain rotation or angulations. These unique features are helpful in recognition of specific products.[31]

Awareness among dental surgeons

There is increased need for dental surgeons to have a good knowledge about forensic odontology as it is useful in identification of an individual and also discover abuse among all ages. Dentists are the health care professionals who routinely assess the head and neck of the patients and have a great chance in identifying the signs of abuse and neglect. Every dentist has to understand the forensic implications associated with their practice.

There is always a lack of involvement among dentists because of lack of training and experience, and due to their limited knowledge in this branch of dentistry. There is also a fear of litigation among dentist which commonly discourages them. "Any physician who fails to identify and report a child with historical, physical and radiological findings that indicate abuse is guilty of professional negligence". There is always a lack in availability and accuracy of dental records which has a great

influence in determining the success of identification.[33]

Conclusion

Forensic dentistry plays a major role in the identification of those individuals who cannot be identified visually or by other means. The unique nature of our dental anatomy and the placement of custom restorations ensure accuracy when the techniques are correctly employed. In this brief overview, some of the traditional and upcoming techniques in this fascinating field are highlighted.

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