REVIEW ARTICLE

Forensic dentistry: A Pedodontist’s perspective

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Abstract
Forensic dentistry delineates the overlap between the dental and the legal professions. Forensic identifications by their nature are multidisciplinary team efforts. Odontologists can examine the structure of the teeth and jaws for clues that may support anthropological age estimates. Apart from dental identification, forensic odontology is also applied in the investigation of crimes caused by dentition, such as bite marks. The importance of pedodontist in forensic odontology is to apply his expertise in various fields like child abuse and neglect, mass disaster, accidental and non-accidental oral trauma, age determination, and dental records. The aim of this paper is to discuss about the pedodontist perspective in forensic dentistry.

Keywords
Forensic, identification, odontology, pedodontist

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History
The case of dental identification was first reported in an 80-year-old John Talbot in 1453.[¹]
Dr. Paul Revere was the first forensic odontologist. He found the body of Dr. Joseph Warren in 1775 through silver and ivory bridges that he had made 2 years back.[¹]
First dental evidence was used in Webster-Parkman case in U.S. Court. Charred fragments of mineral teeth fused to gold were identified in Dr. Nathan Parkman which led to hang Dr. Webster.[¹]
L’Art Dentaire en Medicine Legale was the first dissertation on forensic odontology written by Dr. Oscar Amoedo in 1898. Dr. Oscar is called as father of Forensic Odontology.[²]
Bite marks were used as evidence in 1937 in a person, Chantilly.[¹]
Welty and Glasgow in 1946 created a system in computer that dental data of 500 cards could be sorted in 1 min.[¹]
Kieser-Nielsen assessed the uniqueness of teeth mathematically.[³]
Vale et al. (1976) indicated 6 possible positions of each tooth to demonstrate individuality.[³]
Sogannaes et al. (1982) demonstrated the uniqueness of bite marks even in identical twins by computer comparison.[³]

Sweet and Pretty considered the size, shape and pattern of the incisal or biting edges of upper and lower anterior teeth to be specific to an individual.[³]
Videotape analysis of bite mark evidence was introduced in a California court.[³]
David et al. have used scanning electron microscopy in bite mark analysis.[³]

Terminologies
The word Forensic is derived from the Latin forensic (is): of or belonging to the forum, public, equivalent to for (um) forum + ens – of, belonging to + ic. Forensic medicine is also called as legal medicine or medical jurisprudence.[³]
FDI defines Forensic Dentistry as “it is a branch of dentistry which, in nature of justice, deals with proper handling of dental evidence, evaluation, and representation of dental findings.” Forensic identification is a multidisciplinary team effort depends on positive identification methodologies and presumptive or exclusionary methodologies.[⁴]
Typically this multidisciplinary team involves the cooperation and coordination of law enforcement officials, forensic anthropologists, forensic dentists, forensic pathologists,
criminalists, serologists, and other specialists as deemed necessary.

There are a variety of techniques available from forensic pathology, anthropology, odontology, and entomology that may help to establish the deceased’s identity, cause of death, factors contributing to death, and the timing of death.

Forensic anthropology is the application of the science of physical anthropology to the legal process.

The application of proven methods in scientific manner to collect, process, translate, and to use digital evidence in cybercrimes is called computer forensics. The act of preparing digital data for investigation of crimes is called cyber forensics.

There are three terminologies of age:
1. Pathologic age represents deterioration of many tissues over time. Examine for arthritic changes in temporomandibular joint (TMJ), attritional wear of teeth, root dentine transparency.
2. Physiologic age represents natural or expected changes like development of roots (apical closure).
3. Chronologic age is the time from birth to death.

Role of Pedodontist in Forensic Odontology

Forensic dentistry can be defined as it is a branch of forensic science that utilizes dentistry to identify human remains and bite marks, using both physical and biological dental evidence. Crime against a child may take place within the house or family.

As no fingers are identical, neither two mouth nor two teeth are exactly identical. Gustafson (1962) suggests that the role of dentistry in forensic science for identification of humans came to existence only towards the end of the 19th century.

A dentist plays an important role in identification of victims. Tooth is unique and resistant to destruction. It is a cornerstone in positive identification of persons depending on the characteristics of teeth and jaw. An antemortem and postmortem record makes the identification process easier.

As dental trauma is a regular feature in children due to accident, sports, and child abuse, a pedodontist should have knowledge in forensic dentistry for proper recording of findings to help investigate the legal officers.

Forensic odontologists should know the legal aspects of investigations. Hence the role of a pedodontist is to identify the child victims visually or by other means.

Pediatric dentists can furnish worthy information to physicians about oral and dental manifestations of child abuse and neglect.

Dental Identification Procedures

Positive identifications traditionally involve a comparison of pre and postmortem data, which is considered unique to the individual.

Odontologists can examine the teeth and orofacial skeleton for trauma. They are potentially identifying chips, breaks, recent tooth loss that can indicate antemortem trauma to the mouth. Such injuries could be sustained either as a result of nonaccidental or accidental trauma. Odontologists can also examine the structure of the teeth and jaws and degree of dental attrition for clues that may support anthropological age estimates.

Tooth has been used as the cornerstone in positive identification of living/deceased persons using the unique traits and characteristics of teeth and jaw. Various authors have said that tooth is more unique. Most scientists agree that dental impression is an invaluable tool compared to bite marks, which are more unique than DNA. Same genetic makeup is shared in identical twins but their impressions differ.

Comparative Identification

Human dental identification is required in different situations for different reasons. The postmortem dental remains with antemortem dental records are compared confirm identity. Antemortem records, like intra-extra oral radiographs, clinical photographs, study casts, ortho/prostho appliances, mouth guards all can be used. Congenital and acquired characteristics are compared.

Most commonly comparisons are made based on individual teeth and dental restorations encompassed along with presence/absence of teeth, tooth positions, recent extractions, and eruptive conditions. Morphology of coronal/root portions of teeth, size/location of root canals, foramina, sinuses, and TMJ also can be compared.

Rubber dam punch is used to mark one hole in antemortem and two holes in postmortem radiographs to avoid confusion. Several factors limit the date which is available among children. There is no comparable data regarding restorative care in children and adolescents and clinical indications to take radiographs in children below age five.

Another problem is that normal maturational changes occur with children such as loss of deciduous teeth and the development and eruption of permanent teeth. The latter process can, however, be used in reconstructive identification by establishment of the age at death.

The lack of restorative therapy among many children means that there is limited information for comparison. Even if no fillings exist and treatment need is low, bitewing examinations are almost always a part of the dental record if the child has reached the age of 5-6 years. These images contain radiographic information that could be used in an attempt to match X-rays of the same person taken some years later, including root and pulp structure. If extraoral images are available, the shape and size of the frontal sinus is regarded as unique for each individual and has been used for identification.

By looking at anatomical structures and by undertaking postmortem age stratification, a possible match might not be conclusive, but could be the basis for a combined investigation based on comparison of clothing and personal effects, fingerprints and/or DNA-analysis.
Reconstructive identification (dental profiling)

Age
Age determination is required in living person for:
- a. Birth certificate is not available or if records are suspected
- b. To determine whether child has attained age of criminal responsibility
- c. Assessment in case individual is either unwilling or unable to reveal his identity
- d. In case of disputed marriages, where, marrying couple are supposed to be below the legal permissible age limits.

Age determination is required in dead person for:
- a. To help identification in mass disasters
- b. To know mortality indices of various diseases in epidemiological surveys
- c. Age of the aborted fetus.

Age can be assessed depending on soft tissue changes, hard tissue changes, and dental changes in the oral cavity.[7]

Sex
There are three methods to identify the sex.
- a. Visual or clinical method:
  - Sex differences in tooth size
  - Sex determination using canine dimorphism
  - Root length and crown diameter
  - Dental index
  - Odontometric differences
  - Tooth morphology.
- b. Microscopic methods:
  - Sex determination using barr bodies
- c. Advanced methods:
  Sex can also be determined by using barr bodies. Seno and Ishizu reported in 1973 on the use of the Y chromosome in dental pulp to determine sex differences. F bodies and Barr bodies are stored in dehydrated pulp till 1-year and tissues of the pulp retain sexual diagnostic characteristics when heated upto 100°C for 1 h is observed by Dubby et al. DNA analysis and presence or absence of Y chromatin can reveal the sex by microscopic examination of teeth.[4]

Sex can also be determined by using PCR and enamel protein. There is difference in size and pattern of nucleotide sequence of enamel matrix protein in male and female.[4]

Race
Race determination in skeletal remains traditionally focuses on craniofacial characteristics.[4]

Categories used to determine age, sex, race and individualization:
- Heredity: size and genetic peculiarities
- Wear characteristics
- Pathology: caries and periodontitis
- Restorations – dental fillings and prosthesis such as crowns, bridges, and dentures.[4]

DNA: Role of DNA molecule in identification
Polymorphisms between different individuals like differences in facial appearance, differences in ear lobe conformation, differences in retinal arterial structure, differences in hair color, height, etc., are useful for forensic identification. DNA has a greater likelihood of survival than dental structures, finger prints, scars and facial appearance. DNA is the basis for all blood group types, red cell antigens and protein isoenzymes.[14]

The teeth differ in form and size, but have similar histological structure. The rich sources of DNA like odontoblasts, peripheral nerves, fibroblasts, undifferentiated mesenchymal cells, endothelial cells, and nucleated components of blood are present in soft tissue of pulp chamber. Soft tissue with accessory canals, bone and periodontal ligament fibers, odontoblastic process in dentinal tubules and cellular cementum are less commonly used anatomical sites of DNA.[14]

Obtaining dental DNA
Section the teeth and open the crown to extirpate the pulp. Greater amounts of DNA are obtained by crushing the entire tooth. DNA is extracted from teeth by another method called cryogenic grinding.

Not only can DNA be obtained from teeth for primary identification, but it can also be obtained from family members from reference DNA purposes. Specimens from the spouse and children will permit “reverse paternity” testing using nuclear DNA probes.[14]

The future violent activity of children is identified by the scientific development of both genetics and neuroscience. Monoamine oxidase A - an enzyme that degrades neurotransmitters such as serotonin and dopamine in the brain is coded by the respective gene.[15] Abusive nature and mutations in the MAOA gene increases the risk of violent and antisocial nature. Now, the MAOA mutations are used in genetics with limited success.[16]

Dr. Adrian Raine of the University of Pennsylvania found that antisocial behavior is observed in a fetus with brain abnormality (called cavum septum pellucidum). In other study, the susceptibility of a 3-year-old child to crime at age 23 is due to poor fear conditioning which is indicative of amygdala dysfunction.[16]

Functional MRI is used to detect brain patterns with increased impulsivity in another study. These experimental studies are used to identify the neurological traits in children having criminal tendency.[18]

Other methods of identification of human remains
Thermoplastic material is used to record the morphology of the human dentition to identify missing persons.[17]

It is the opinion of the American Board of Forensic Odontology that this technique is of limited value when used for the dental identification of children.[17]

The technique which uses Dr. Wagner’s material to record the morphology of the dentition is one that has merit in aiding in
the identification process of human remains. It may be of some use in cases where no other antemortem (before death) dental information is available for comparison. The imprint of teeth in the thermoplastic material might be of use to help identify an individual by comparing unique morphological features of the teeth.\textsuperscript{[17]}

This technique has a specific use in children. These include, but are not limited to:
1. Accurately taking the impression on a young child.
2. The continuous growth and development of the oral cavity in children produce changes in the teeth and oral structures.
3. Decomposed remains of children can present special dental identification challenges by using few teeth for comparison such as single rooted primary teeth, resorbed roots, and missing successive permanent tooth.

In such cases, dental radiographs would be preferable to a thermoplastic bite impression for identification purposes.\textsuperscript{[17]}

### Technologic Aids in Forensic Investigation

#### Photography

Photography is one of the most important applied protocols of forensic dentistry. It is the most important skill for odontologist and pathologist to photographically record injuries as they appear on skin. Frequently photographs are the only permanent record of the injuries to the victims.\textsuperscript{[18]}

Various techniques that are used in forensic photography:
1. Visible light photography
   a. Digital photography
   b. Visible light color photography
   c. Visible light black and white photography
2. Alternate light imaging and fluorescent techniques
3. Non-visible light photography
   a. Reflective long-wavelength ultraviolet photography
   b. Infrared photography.\textsuperscript{[18]}

#### Radiography

Radiographs of the antemortem and postmortem records are compared to identify remains.\textsuperscript{[8]}

Radiographs are used to observe the different stages of mineralization morphologically. These are also based on the stage of crown and root formation, tooth eruption, and stage of mixed dentition.\textsuperscript{[2]} The teeth and bones of the craniofacial complex are used to determine the age, sex, and race of a person to differentiate one individual from others and one population from other.\textsuperscript{[19]}

The parameters used for radiographic interpretation are morphology of tooth and roots, retained tooth, supernumerary tooth, missing tooth, tooth fracture, periodontal bone loss, any pathology related to bone, shape of the cavity, restorative and endodontic fillings, and prostheses.\textsuperscript{[20]}

#### Conventional radiography

Conventional radiography is used to compare the antemortem images with postmortem images.\textsuperscript{[21]}

Anatomical findings like the morphology of pulp, alveolar bone, and changes due to dental treatment can be observed using conventional radiography.\textsuperscript{[21]}

The following steps are used in this technique:
1. Digital radiographs with a scanner and a video camera or acquisition of images from X-ray coupled with CD-ROM.
2. Processing of images based on image superimposition and subtraction using the proper software.\textsuperscript{[22]}

#### Computed tomography (CT)

CT is a good radiographic technique to use in forensics because of less superimposition and small differences in the density of structures.\textsuperscript{[23]}

CT has added advantages like segmentation, good quality, color, transparency, and manipulation in various measurements.\textsuperscript{[24]}

Postmortem facsimile image can be created using antemortem CT image by using accurate craniometric points.\textsuperscript{[24]}

#### Identification by Frontal Sinuses Pattern

This is a well-developed technique for identification in forensic anthropology. Antemortem and postmortem radiographic and tomographic images can be compared by observing the differences in morphology, number of cells, and their presence.\textsuperscript{[22]}

#### General Identification through Radiology

The development of bone is continuous and finish with the epiphyseal union. Different radiological methods are used for age estimation. The relationship between chronologic age and developmental age of the bone varies with individual and environment and it also depends on the method used.\textsuperscript{[25]}

Digital radiographs can be used to identify and compare the relationship of root and supporting structures of the teeth in antemortem and postmortem records.\textsuperscript{[26]} If there is the absence of an antemortem record, the postmortem record is used to exclude identity by using other antemortem record.\textsuperscript{[16]}

#### Computer software technology

Special software was designed called the Palatal Rugae Comparison Software (PR S Version 2.0) to match the clinical photographs taken using a SLR digital camera. The software recorded an accuracy of 99% in the identification of individuals whereas manual methods have shown high false positive and negative cases.\textsuperscript{[27]}

Computer software technology is also used for forensic facial reconstruction. Depending on how powerful the computer is, digital reconstruction of the soft facial parts can be achieved in seconds. Computer programs create three-dimensional reconstructions by manipulating scanned photographs of the cranial remains and stock photographs of the facial features.\textsuperscript{[28]}

Width, the length, and the height of the maxillary sinuses were measured in CT scans with the application of software for gender determination.\textsuperscript{[24]}

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With the application of software technology it is possible to artificially color areas with equal intensity values and depict a 2D image as a pseudo-3D surface object to assess bitemarks.\cite{28}

Based on an analysis of two large datasets, individual dental patterns were determined using a special computer program (OdontoSearch) and were found to be generally unique, or at least very uncommon.\cite{28}

**Palatal rugae pattern**

Palatoscopy or palatal rugoscopy is the study of palatal rugae in order to establish a person’s identity. It is a viable alternative for identification purpose. It is the ideal forensic identification parameter because of its uniqueness, postmortem resistance, and stability. Once formed, they do not undergo any changes except in length, due to normal growth, remaining in the same position throughout an entire person’s life.

There may be less pronounced changes in burn victims. In edentulous cases, the evidence can be taken not only from the hard palate directly, but also from the mucosal surface of the dentures.\cite{29}

**Lip prints**

Lip grooves are permanent and unchangeable like fingerprints and palatal rugae. The identification of lip patterns is possible from 6th week of intrauterine life. The mucosal area which is covered with wrinkles and grooves is used for identification. Cheiloscopy is determined by lip anatomy, thickness, and position. Lip prints should be photographed and enlarged. If lipstick is present, it should be analyzed in order to determine its constitution.\cite{29}

**Dental Profiling**

**Ethnicity**

Osteological clues are used to determine like,

- Basic etiology – whether it is primarily biochemical, hormonal or activity-related in order to predict its variation pattern.
- Range of variation by sex in various racial/ethnic groups.
- Manifestation by age – the age at which it appears and its pattern of change from childhood to old age.
- Influence of health, nutrition, occupation or other circumstances.
- Secular changes in expression.
- Whether the characteristics are real, but temporary.\cite{30}

From a dental perspective, both the mandible and dentition reflect racial characteristics. Forensic odontologists assist in the process whereas forensic anthropologists provide the details of osteological studies.\cite{31}

**Sex**

Morphology of the teeth like crown size, root lengths will assist in determining the sex of the remains.

General findings like skeletal development maturation, sexual characteristics, degenerative, and hyperostotic changes with aging, size of the femoral head are helpful to identify human remains. Sex differences in dentition are based largely on tooth size and shape, canine dimorphism, root length, and crown diameter.\cite{4}

**Role of skull and mandible to identify sex**

Mutilated bodies of humans due to mass disasters are identified by establishing the sex of victims in forensic dentistry. Bony characteristics of the skull and mandible may be useful in sexual identification. The male skull tends to range from mesocephalic to dolicocephalic; the female skull is more likely to be mesocephalic to brachycephalic. The male mandible is larger and more rugged with a wide ascending ramus.\cite{4}

**Age**

Age estimation is an important part of the identification process.\cite{7}

**Steps of age estimation**

- **Visual assessment** – A gross clinical examination of soft tissues and teeth may give a good estimate of chronological age.
- **Radiographs** – Intraoral periapical radiograph and orthopantomograph will give information about the size of the pulp.
- **Extraction and preparation of single tooth** – Single intact teeth, half sectioned teeth or ground sectioned teeth are used for age estimation.\cite{7}

**Methods of age estimation**

- **Estimation of age by skeletal means**: Different procedures are there like,
  a. Analysis of length of long bones
  b. Epiphyseal union
  c. Closure of fontanelle
  d. Ossification of hand and wrist bones
  e. Closure of skull sutures and palatine sutures.
- **Estimation of age by teeth**: Different approaches are used like,
  a. Age assessment in prenatal child
  b. Age assessment in neonatal and postnatal child
  c. Age assessment up to 14 years
  d. Age assessment up to 21 years
  e. Age assessment after 21 years.\cite{7}

**Other Methods**

- Morphological methods
- Radiological methods
- Biochemical methods.\cite{5}

**Height**

Femur and humerus are the two bones which are used commonly to estimate the height of an individual. Multiply the length of
the femur which is measured in centimeters by 2.6 and add 65 to calculate the height in centimeters. Multiply the length of the humerus which is measured in inches by 2.6 and add 65 for the female victim. Multiply with 2.9 and add 27.9 for a male victim.[31]

Age of the victim is an important factor for estimation of height because children's bones aren't completely fused.[31]

**Crime Investigation**

The forensic odontologist works in the investigating team, according to the nature of the disaster. Depending on the nature of the disaster, along with the forensic odontologist, the team contains a coordinator, experienced specialists, and pathologist.[32] As teeth are the calcified structures, they can resist fire. Restorations are also heat resistant unless they are exposed directly to the flame. Preservation is possible in most cases.[33]

Preparedness is the most important thing in the identification of mass disaster. Successful mock disaster scenarios are being conducted to prepare the dentists for disasters. Proper preservation and storage of evidence is critical if the analysis is to be accomplished in a reliable, efficient manner.[34]

**Bite marks**

Apart from dental identification, forensic odontology is also applied in the investigation of crimes caused by the dentition, such as bite marks. Forensic odontologists can help physicians to evaluate the bite marks due to abuse.[35]

As each individual has a characteristic bite pattern, the dental models of suspected abuser should be used to match the photographs or impressions of the bite. Polyvinyl siloxane impression should be made for bite mark immediately after swabbing it. This is used as a three dimensional model. Photographs should be taken daily for 3 days for documentation.[9]

**Child abuse**

**Physical abuse**

Physical abuse results in the face, head, and neck injuries. Accidental injuries are common in the oral cavity due to physical abuse. Dentist should have knowledge to distinguish physical abuse with other types of abuse by observing history, multiple injuries, and stages of healing.[9]

Injuries due to child abuse include tooth fracture, avulsion, luxation injury, laceration of frenum, lip bruising, maxilla, and mandible fractures. As a primary health care provider, the dentist is necessary to report the child abuse to respective authorities.[9]

**Sexual abuse**

Injuries to mouth are rare in children who are afflicted with sexual abuse.[36]

All suspected or diagnosed sexual abuse cases should be intimated to law enforcement agencies or child protection cell for proper investigation.[35]

**Dental neglect**

According to American Academy of Pediatric Dentistry, dental neglect is defined as the "willful failure of parent or guardian to seek and follow through with treatment necessary to ensure a level of oral health essential for adequate function and freedom from pain and infection."[38]

Poor socioeconomic status, isolated families, poor oral hygiene, and parental negligence results in failure to obtain appropriate oral health.[36]

**Conclusion**

Dental evidence plays a major role in establishing the identity of the unknown body and living victims of child abuse, sexual assault, and other domestic violence. At present, the dental clues are used most commonly in identification. A Pedodontist plays an important role in child abuse and neglect, bite mark analysis, criminal/natural deaths and injuries, etc. In future, digital/computer forensics is necessary in identification. DNA fingerprinting, the role of teeth as a source of DNA material is most commonly used in future forensics.

The forensic odontologist must be dedicated to the legal system and adhere to the ethics. Hence, the pedodontist is concerned with the correct management, examination, evaluation, and preservation of child dental evidence in criminal or civil legal proceedings in the interest of justice.

**References**
