Journal of Advanced Clinical & Research Insights (2016), 4, 59–63

REVIEW ARTICLE

Forensic radiology: An emerging science

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Keywords
Dental identification, dental profiling, forensic radiology

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Received November 2016;
Revised January 2017

doi: 10.15713/ins.jcri.158

Abstract

Forensic maxillofacial radiology is a specialized area of medical imaging in which radiological techniques are utilized to assist physicians and pathologists in situations pertaining to the law. Radiology has a wide arena of usage in forensics in terms of dental identification, identification based on anatomy, and using various maxillofacial skeletal landmarks. Since the radiographs are the quick, easy, simple, inexpensive and nondestructive method of obtaining information about age, sex, race of the victim, it is an indispensable aid in identification. With the advancement of newer technologies, more accurate information is obtained for identification as well as in the facial reconstruction of the unknown deceased person. This paper, therefore, aims to revisit the role of oral and maxillofacial radiology in forensic science where radiographic methodologies play a pivotal role to determine identity using the tooth and its associated orofacial structures in conjunction with advanced imaging modalities such as computed tomography and magnetic resonance imaging which are gradually being added to the forensic arsenal.

Introduction

Forensics can be understood by the quote of the famous fictional detective created by Sir Arthur Conan Doyle, Sherlock Holmes. "It has been an axiom of mine, that the little things are infinitely the most important." From murders, to sexual abuse, to mass disasters, forensics has really gained importance over the years. Even the minute details of human corpses help various scientists in solving various crimes as well as in the identification.

The word "Forensics" come from the Latin word, "Forens(is)" which means belonging to the forum, public or equivalent to. At present, the definition of forensics, followed by many dictionaries around the world is, "the use of science and technology to investigate and establish facts in criminal or civil courts of law."[1]

The term, "forensic science," refers to a group of scientific disciplines which are concerned with the application of the respective scientific area of expertise to law enforcement, criminal, civil, legal, and judicial matters. There are many subspecialties associated with forensic sciences such as Forensic Medicine/Forensic Pathology, Forensic Anthropology, Forensic Odontology, Forensic Radiology, Forensic Entomology, Forensic Toxicology, and Forensic Psychiatry.[2,3]

Forensic Radiology

Forensic science requires an integrated, multidisciplinary approach for criminal identification and one of the most important fields is forensic radiology. Radiologists are an integral part of the forensic science team, and their importance is increasing every year. Forensic radiology entails assessment, modulation and interpretation of radiological examinations, and procedures, all of which have to do with the court of law. Radiographic analysis is crucial in the identification and investigations of a crime scene.[2]

Radiographs are usually taken during postmortem examinations and they help in locating the presence of any foreign bodies. Furthermore, the documentation of the presence of fractures and the analysis of any other injuries are special features of radiographs. It is also always necessary to have the ante-mortem radiographs of the same individual, as comparisons between this and the postmortem radiographs can be made for better identification of the individual. This is why forensic radiology plays a key role in both odontology and anthropology.[4]

Radiographic examinations are also important in deducing any sort of medical negligence as well as nonaccidental injuries. This is particularly important especially in women and children,

where cases of abuse and improper medical care are more prevalent. Biological aging can also be deduced by radiographic examination.[4]

These are the main reasons why clinical radiologists and forensic experts need to work in tandem. They should be aware of their respective responsibilities in the court of law. Storage of radiographs along with the organization of records is important in forensic radiology, and so its role has a lot of scope for the future.[5]

History of Forensic Radiology

1895: This was a very significant year in forensic radiology because it was the year that Wilhelm Conrad Rontgen incidentally discovered, "A New Kind of Ray." This accident is what has shaped the field of radiology today.

Weeks later, these X-rays were tested for forensic use for the first time. At that time, scientists were encountering problems in processing the radiographs. A single image would take close to 70 min. It was first used for solving a murder case in North America.[2]

1919: This was a significant year in North America, as radiology was accepted as a means of forensic identification in solving crimes, by the courts. This was also incidentally the first time a president was radiographed. In 1912, the President of U.S.A., Theodore Roosevelt was shot in the chest during campaigning and survived. He was radiographed and it was clearly seen that the bullet was embedded in a broken right rib. This was used as an example and was submitted to the court in 1919. This further proved the usefulness in radiology in detecting gunshot wounds.[6,7]

1940: As early as 1896, W. Koenig started taking radiographs of teeth, which led the way for the development of forensic odontology. The first documented case where dental radiographs played a major role in individual identification was Adolf Hitler.

1967: Computed tomography (CT) by Sir Godfrey Hounsfeld and magnetic resonance imaging (MRI) was introduced. Within CT, various new techniques have also developed, and one such technique is multidetector CT. This has become largely popular in forensic work and is considered the "Gold Standard," currently for comparing ante-mortem and postmortem radiographs.

Scope of Forensic Radiology

Like many other scientific disciplines, forensic radiology also involves various aspects such as service, education, research, and administration. Over the years, diagnostic radiology has undergone rapid changes in the technology as well as the amount of utilization and this is likely to broaden even further in the future. According to B.G. Brogdon, the scope of forensic radiology can be classified as follows.[2]

Classification

1. Service
   - i. Determination of identity
   - ii. Evaluation of injury and death
     - a. Accidental
     - b. Nonaccidental
       - Osseous injury
       - Missiles/foreign bodies
       - Other trauma
       - Other causes.
   - iii. Criminal litigation
     - a. Fatal
     - b. Nonfatal.
   - iv. Civil litigation
     - a. Fatal
     - b. Nonfatal.
   - v. Administrative proceedings.
2. Education
3. Research
4. Administration.

Forensic Radiology in Dentistry

Forensic dentistry deals with the examination of dental evidence along with the proper evaluation of dental findings. According to the Federation Dentaire Internationale, forensic dentistry is defined as, "The branch of dentistry which in the interest of justice, deals with proper handling and examination of dental evidence with proper evaluation, and presentation of dental findings." Human dentition, till date, has been one of the most reliable and unique tissues in the human body and is also well insulated by the supporting alveolar bone structure and oral musculature. Because of this, even if the remaining parts of the body are highly damaged beyond identification due to any tragic incidents, the dentition still remains intact. It sheds light on the age, sex, and nationality of the deceased person.[8]

Radiology has been used enormously in conventional dental identification. It is highly based on the anatomy as well as the comparisons of the skeletal landmarks in both the ante-mortem and the postmortem records. By viewing these records, one can determine the ethnic group, the skin color as well as the oral cavity fluids for human identification. It is an important for the forensic odontologist to take radiographs of the tooth bearing areas for identification purposes especially in mass disaster incidents. Age estimation is also done using intraoral radiographs.[8,9]

Dental identification

Much before X-rays were invented in 1895, dental identification was done by the "visual Method," where the naked eye was used. A few years later, radiology started aiding the odontologists in identification. The modern use of maxillofacial radiology may be

either comparative or reconstructive in nature. The comparative type compares both the ante-mortem as well as the postmortem radiographs. The reconstructive type uses the radiograph as an aid to create a biological profile for a deceased individual, whose identity remains unknown. When the identity is confirmed, then the usage of comparative radiography is contemplated. There is a particular algorithm for dental identification using radiographs.[8,9]

1. Examining the ante-mortem radiographs for quality, time, and type of examination.
2. Examining the postmortem specimen, and expose radiographs that will duplicate the areas of interest seen in ante-mortem films using similar image geometry, suitable exposure factors, and archival processing.
3. Using a system of marking or mounting the films so that their identity as postmortem or ante-mortem films is known.
4. Visually analyzing the radiographs, taking into account ancillary information such as dental chart notations, dental models, and photographs.
5. Tabulating the points of concordance and explain, if possible, discordant points between the ante-mortem and postmortem radiographic examinations.
6. Making a decision as to whether the materials provided allow the observer to make a positive identification a possible identification or a negative assessment.[9]

Usually, whenever a comparative radiographic evaluation is required for identification, the experts focus on evidence of dental interventions such as restorations, crowns, and extractions. If radiographs are absent, various visual means of identification can be used such as dental charts and fingerprint records or study models.[9,10]

Anatomical identification

No evidence of dental interventions usually makes the forensic expert rely on anatomical landmarks to compare both ante-mortem and postmortem radiographs. Features such as crown morphology, root size, and pulp morphologies play a major role in individual identification. The spatial relationships of the posterior teeth can also be compared using ante mortem and postmortem radiographs.[11] This is particularly useful in incinerated remains, where the crowns are damaged or lost. However, analyzing the facial bones is much more difficult, because of the anatomical complexity. There are a large number of overlapping structures in the maxillofacial region, making comparisons virtually impossible. The only landmark which can be used for ante-mortem and postmortem comparisons is the frontal sinus. Various radiographs involving the sinuses, i.e., waters view, can be used for comparisons in these cases (Table 1).[8,9,12]

Dental profiling

Radiographic examinations play a key role in creating a profile of the individual before death. An example of this is via the dentition, which was lost during postmortem procedures. The anterior teeth can be reconstructed to assess and define their angulation. This allows for the approximation of the number and alignment of the anterior teeth.[13]

Medicolegal cases

Forensic maxillofacial radiology plays a major role in medicolegal cases, where the suspect can be distinguished as either a juvenile or an adult. Dental radiography is invaluable in identifying people in mass casualty cases. Newer advances, like the handheld portable X-ray system has been instrumental in rapid acquisition of images at the site of the crime, casualty, with no enhanced radiation levels.[14]

Forensic radiology is also helpful in evaluating injuries sustained by the victims. One can determine from the injury whether it is an intentional injury or an accidental injury. Traumatic injuries of the skull can be evaluated by analyzing the direction of impact or the point of impact. Furthermore, the shape of the object and the weapon used can be determined. Evidence of strangulation shows fractures of the hyoid bone or the cornua of the thyroid, which is visible on radiographs. Newer modalities such as computer-assisted tomography and micro-CT are also gaining popularity in the assessment of the wound, and the type of weapon used.[6]

Age determination

The main goal of age determination is to assist in the development of the profile of the deceased. In the event of incomplete formation of permanent dentition, the forensic odontologist can assist by narrowing down to the age of the deceased.[9]

Craniofacial reconstruction

This aspect of forensic medicine became popular when there were no ante-mortem records available. It was founded by encompassing the specialties of forensic dentistry, forensic medicine, anthropology, and anatomy. For example, in exhumed war victims, whenever teeth and fingerprint analysis is impossible, the trained forensic odontologists are included in the team. Their job is to identify unknown bodies using computer science and medical imaging. Recent studies have shown the increasing importance of three-dimensional imaging in craniofacial reconstruction, and this has been demonstrated via the usefulness of modalities like CT and MRI.[15]

Radiology has always been used enormously in conventional dental identification, based on the anatomy as well as the comparison of various maxillofacial skeletal landmarks in both ante-mortem and postmortem records. There are many structures which are involved for radiographic identification in forensics. Variation in these structures when comparing ante-mortem and postmortem radiographs, allow for the identification of the individual.[2]

Table 1: Radiographic features appreciated in identification[8]

Structure	Features to look for
Teeth	Teeth present – Erupted, unerupted, impacted Teeth absent – Congenitally missing, lost ante-mortem, lost postmortem Tooth type – Permanent, deciduous, mixed, retained primary, supernumerary Tooth position – Malposition Crown morphology – Size and shape, enamel thickness, contact points Crown pathology – Enamel pearls, cervical enamel extensions, dentigerous cysts Root morphology – Size, shape, structure, number, divergence of roots Root pathology – Root fracture, dens evaginatus, root resorption, root hemisections, gemination, fusion, concrescence, hypercementosis, dilacerations Teeth pathology – Amelogenesis and dentinogenesis imperfecta, dentin dysplasias Pulp morphology – Size, shape, and number, secondary dentine Pulp pathology – Pulp stones, root canal therapy, retrofills, apicectomy Periapical pathology – Abscess, granuloma or cysts, cementomas, condensing osteitis Periodontal ligament – Thickening, widening, lateral periodontal cysts
Foreign bodies	Dental restorations – Metallic, laminates, dental implants, bridges Others – Unretrieved amalgam particles, broken files, bullets
Alveolar bone	Alveolar process - Height, contour, density of crestal bone, enostosis, bone loss, trabecular bone pattern, residual root fragments Lamina dura – Pattern of lamina dura
Anatomical structures	Maxillary sinus – Size, shape, cysts, foreign bodies, fistula, relationship to teeth Maxilla – Anterior nasal spine, incisive canal (size, shape, cyst), median palatal suture. Mandibular canal – Mental foramen, diameter, anomalous, relationship to adjacent structures TMJ joint – Condyle, coronoid process-size and shape TMJ abnormalities – Hypertrophy/atrophy, ankylosis, fracture, arthritic changes
Other pathologies	Developmental cysts, salivary gland pathologies, reactive/neoplastic, metabolic bone disease, focal/diffuse radiopacities, evidence of surgery trauma-wires, surgical pins

TMJ: Temporomandibular joint

Conclusion

Forensic radiology has rapidly gained importance in the field of forensic sciences worldwide. Forensic experts can rely on radiographs for human identification as well as for estimation of age, gender, race, and stature. The socioeconomic status and bitemark analysis to identify suspects can also be derived from radiographs. The advent of newer radiographic techniques have definitely made the job for the forensic dentist much easier. However, for forensic radiology to be more effective, it should be used in conjunction with other forensic methodologies, so that this multidisciplinary approach can yield more accurate, less time-consuming results at cheaper costs. It is also important to understand the significance of record-keeping, especially radiographs. The forensic team should always be well-acknowledged regarding the importance of dental radiography in forensic sciences and it should always be included in the normal protocol of examination. Forensic radiology and odontology are still gaining importance in developing countries such as India, where the knowledge of the field is still relatively inexperienced. The future looks bright though and in a few years to come, the demand for the maxillofacial radiologist will definitely be on the rise and will be an integral part of the forensic team.

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How to cite this article: Tarani S, Kamakshi SS, Naik V, Sodhi A. Forensic radiology: An emerging science. J Adv Clin Res Insights 2017;4:59-63.