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Research Article

FORENSIC ODONTOLOGY V/S RADIOLOGY

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ABSTRACT

Forensic radiology comprises the performance, interpretation and reporting of diagnostic radiological data. The indication of radiology in forensic sciences have been started over a century since a radiograph was initially introduced as evidence in a court of law and now have expanded with new technologies and techniques for capturing radiographic images with great ease. Initially radiology was useful only in detecting the cause of injury and for documentary purpose. Later it started using for detecting and solving criminal activities and now it is also applicable in improving the safety of the society. Forensic radiology plays an important role for identification of humans in mass disaster, criminal investigations and evaluation of cause of death. The virtual autopsy appears as a helpful and complementary tool for dental and medical cadaveric examination.The purpose of this article is to enlightened the role of maxillofacial radiologist in forensic science and radiograpohic evaluation of various landmarks of head and neck region and their characteristic features that can be used as valuable forensic tool.

INTRODUCTION

The word "Forensic Odontology" is derived from a Latin word 'forum' which means where legal matters are discussed and Odontology refers to the study of teeth or dentistry. According to Federation Dentaire Internationale [FDI], Forensic Dentistry as the branch of dentistry in the interest of justice deals with proper handling and examination of dental evidence with the proper evaluation and presentation of dental findings.[1] Keiser-Neilson(1970)[2] define forensic odontology 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." It has been said that the forensic odontology was initially used in 49 A.D.Earlier reported dental identification case was that of Lollia Paullina.[2]

Crime rate, road traffic accidents, terrorism, wars includes bomb blast and mass disasters like flood, earth quakes, tornados are drastically increasing in modern era and proper identification of victim is very necessary but at the same time it is difficult also.[3] The applications of radiology in forensic science was first introduced in 1896 by Prof. Arthur Schuster, a year after the discovery of X-rays, to demonstrate the presence of lead bullets inside the victim's hand.[1] The introduction of radiology in forensic science is a breakthrough that includes collection of data and interpretation most commonly for identification purpose. The comparison between postmortem radiographs and antimortem radiographs provides better information to forensic radiologist. Even in the absence of antimortem records, it also provides information related to age, gender and race of victim.[4] There are various aspects where forensic radiologist plays an important role for example human identification, cause of death(autopsy), gender, age, race of victim, mass disaster victim identification.

Radiographic methods that can be used for detection are conventional intraoral and extraoral skull radiography, OPG, computed tomography, cone beam tomography, ultrasonography and magnetic resonance imaging.

DISCUSSION

Human Identification

Forensic odontology deals with different kinds of injuries to the human body, for example: ripped, lacerated, carbonized, macerated, putrefied and skeletonized. There should always a single objective that is to establish the human identity.[5]

There are various reasons for identification of found human remains are given in table below.[6]

Radiographically assisted dental identification may be comparative or reconstructive type. In comparative identification ante-mortem records are compared to that of suspected postmortem record.

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Purpose	Common reason for human remains identification
Crime investigations	To know the identity of victim and his cause of death.
Marriage	In few religions, person cannot remarry until they do not get proper confirmation of death of their partner.
Monetary	Only after positive confirmation of death, the family memberts get pensions payment, life insurance and other benefits.
Burial	Some religions requires proper confirmation of victim so that their remain will be buried according to their rituals.
Missing individuals	Identification of human remains to suspect a person who is missing for a prolonged period.
Mass disasters & Accidents	For victim identification and determining total number of deaths in disasters.

A record of recovered ante-mortem radiograph that can be bitewing or IOPA (Intra-oral peri-apical) or panaoramic radiograph spanning many years and the latest films are chosen to compare among that. The post-mortem films should reproduce the angulations of ante-mortem films to duplicate the same results.[7] Anatomical details adopted as parameter include: number/arrangement of teeth (present/ missing/ rotated/impacted/extra teeth), shape of teeth-crown and roots, anatomic landmarks, nutrient canals, sinuses, caries or periodontal pathology, dental restoration, endodontic treatment, intra- & inter-coronal posts

Age and Gender Determination:- It is important part of almost every identification process, especially when information can only get from hard tissue of the body as the decomposition process is slow in these tissue. Patterns of aging can be detected on radiological examination. The ageing of human remains is based upon a detailed knowledge of biological changes that occur during development, growth and maturation. There are following methods are discussed that helps in age determination by radiographic methods.

Cranial suture:- **T**he skull bones are held together by strong, fibrous, elastic tissues called sutures. Four main sutures of skull are Saggital, Coronal, Lambdoid and Squamosal. Radiological examination for obliteration of cranial suture also used for age estimation. The progression towards fusion has been divided in three categories: 1- Not commenced, 2- In process of fusion and 3-Fused according to Fredric rating scale[8].

Rentoul and Smith, H (1963)[8] studied the development and consolidation of the bones of the skeleton, which ossify in cartilages occurs, as a rules, about two years earlier in females than in males, but obliteration of sutures of vault of skull sets in a little later and proceeds slowly in females than in males i.e. the obliteration of vault suture occur earlier in males than in females. In a study by Revelo and Fishman(1994), the mean anteroposterior percentage of mid palatal suture fused upto the end of skeletal growth.[9]Verma R.K *et al* 2010 determine the age of individual in the fourth decade to seventh decades by radiological finding and concluded that in males complete fusion of coronal suture takes place at 52 years and in females it takes place 56 years. Squamosal suture is visualized in lateral view of skull x-ray only, it get fused at the age of 80 yrs.[10]

Trabeculae pattern of jaw bones:- Irregular mesh of trabecular bone seen at the core of bone. In most cases, the intertrabecular spaces increased, the trabeculae seemed less mineralized, and the compact bone became thinner and more porous. Osteoporosis is a condition characterized by a loss in bone mineral density and micro-architectural deterioration in bone tissue leading to fractures.[11] Because 70% of bone strength is determined by skeletal bone mineral density (BMD) and the remaining 30% by factors determining bone quality, such as bone turnover rate, BMD measurement of the general skeleton is an important indicator of risk of fractures for individuals. Menopause is a major risk factor for osteoporosis, and most postmenopausal women are at risk of osteoporosis and consequent fractures.[12] Also the nutritional deficiency is common in females like calcium deficiency is common that further causes the less mineral bone density and more incidents of fracture.

McCalden RW *et al* (1993)[13] studied that in addition to trabecular bone loss, declines in cortical BMD associated with increased porosity also contribute to bone fragility with aging. Wanatabe P.C.A *et al* (2001)[14] showed that osteoporotic females (postmenopausal) shows less number and less complex architecture of bony trabeculae. So women are more prone to fractures.. Macdonald HM *et al* (2010)[15] found that in men have larger bone size and higher -quality indices of trabecular morphology than women due to post menopause-associated increases in osteoclastic activity.

Cortical bone thickening:- A bone mineral density(BMD) test is the best way to determine bone health. The appearance of inferior mandibular cortex and its width in terms of Mandibular cortical index on dental radiograph will determine BMD. Dual-energy X-ray absorptiometry (DXA) can be used to determine BMD.Hashimoto M *et al* 2006 stated that 95% of women aged 50 years and older had osteopenia or osteoporosis.[59] Kavitha MS *et al* 2012 that shows the sensitivity and specificity of the cortical measurements for identifying the development patients were 90%.[16]

Nutrient canals:- These are circulating canals, interdental canals and vascular channels. These are called the perforating canals of Zuckerkandl and Hirschfeld (nutrient canals), which house the interdental and interradicular arteries, veins, lymph vessels and nerves.

Prashant P Jaju (2007)[17] observed that the incidence of nutrient canals was more in patients who had hypertension associated with other conditions, like diabetes mellitus, periodontal conditions, or disuse atrophy and also the incidence of nutrient canals in hypertensive and normotensive patients was almost the same and prevalence is more at 50-60 years of age. Patni(1985)[18] correlated the radiographic appearance of nutrient canals with age race and pathological conditions like hypertension, diabetes and calcium deficiency. Singh G *et al* (2011)[19] observed as the age advances prevalence of nutrient canals are more prevalent. Pandarinath B.G observed that the prevalence of nutrient canals was higher in patients with periodontitis and in the age group 55-64 years.[20]

Mandibular canal and foramen: **T**he mandibular canal and foramen is situated at childhood just above the level of the mylohyoid line. During adulthood the mandibular canal runs

nearly parallel with the mylohyoid line and in old age mandibular canal is close to the alveolar border. Tebo HG *et al* (1950), Warwick R *et al* (1950), Montagu MFA *et al* (1954) observed that in normal adult mandible with teeth, the mental foramen is located halfway between the lower margin of the mandible and alveolar crest in a vertical line in which 50% of cases it is located at the edge of second premolar root, in 20-25% it is between first and second premolar and in 24 % , it is behind the second molar.[21] Akgul & Toygar (2002) concluded that the morphologic alterations occurs with increasing age and also between the genders.[22] Chandra A *et al* 2013 observed that the distance from lower border of the mandible to the mental foramen exhibit sexual dimorphism in the north Indian population as this distance is higher in males than females.[23]

Styloid process:-The styloid process is a bony projection, situated immediately anterior to the stylomastoid foramen. It is of cylindrical form and projects downwards from the inferior surface of the temporal bone towards the front, downwards and medially narrowing towards the tip. The average length of styloid process was 3.67±0.62 cm. The mean age of the patients with elongated styloid process was 37.95±14.58 years.[24] Kursoglu *et al* (2005) and Anbiaee and Javadzadeh (2011) used panoramic radiograph for the measurement of SP length and indicated that SP length was associated with increasing age and indicated continuous calcification type as the most common type of morphology in their studies in which OPG was used as diagnostic tool.[25]

Teeth:-Teeth are less susceptible to nutritional, hormonal and pathological changes since childhood hence they more definitive for age estimation during various developmental stages. Dental age estimation is based on appearance of tooth germs, earliest detectable trace of mineralization or beginning of mineralization, degree of crown completion, time of emergence of the tooth in the oral cavity, degree of root completion of erupted or unerupted teeth, degree of resorption of deciduous teeth and measurement of open apices in teeth.[26] Various illustrious methods applied for age estimation are as follows:

Schourand Masseler in 1941 described 21 chronological steps from 4 months to 21 years of age and published the numerical development charts for both deciduous and permanent teeth. American Dental Association(ADA) has periodically updated and published these charts in 1982 which specifically aids incomparing the calcification stages of teeth on radiographs with the standards.[26,27]

Moorees, Fanning and Hunt (1963) reported 14 stages of mineralization for developing permanent teeth and determined the mean age for the corresponding stage was determined. Infants of 6 months upto the adults with developing third mandibular molar were included in the data. Remarkably, female development was ahead of the male and the root formation stages exhibited variation compared with crown formation stages.[28]

Demirjian, Goldstein and Tanner (1973) considered seven mandibular permanent teeth of each quadrant excluding the third molars. They determined eight stages of tooth mineralization which were the indicators of dental maturity of each tooth. This method is the utmost developed of all dental age surveys. The drawbacks of this method are that it does not include the developing third molar and the mandibular teeth need to be present for the survey to be applicable.[1]

Age estimation can be done with Kvaal's formula,which was given by kvaal's *et al* in 1995[29], a new age estimation formula was derived from obtained length and width ratios

Paranasal sinuses:- Paranasal sinuses are group of four paired air filled spaces that surrounds the nasal cavity. These sinuses are maxillary sinus, frontal sinus,sphenoidal sinus and ethmoidal sinus.There is a considerable variation in size and shape of the paranasal sinuses with age and even between the right and left sides. The main characteristics of the paranasal sinuses are pneumatic, their anatomy is complex and varies from person to person.

Porbonikova *et al* (1974) observed the growth begins on 13 months of age and increases upto 20 years of age. Karakas S (2010) stated that highest averages of paranasal sinuses is about 25 years.[30]Libersa *et al* (1957) have observed the frontal sinuses begin developing between 2 and 3 years. Krogman (1962) reports that the frontal sinus become an extension of the nasal cavity after the second year of life and grows progressively until the age of 20 years. Cristiane RR (2004) and Tatlisumak E (2008) observed that the frontal sinuses are not detectable radiographically until the age of 4 to 6, and then gradually become bigger and more complex. Their development is fast until puberty and normally is completed by 20 years old.[31] Ariji Y (1995) observed that the volume of the normal maxillary sinus increases upto twenty years and then decreases. There is no significant difference in the size of maxillary sinus between 50-79 years. When teeth are lost, the bone reverts to its infantile shape. Ikeda A (1996) concluded that in inflammatory changes like chronic maxillary sinusitis etc. the volume of maxillary sinus decreases.[32] Yonetsu K *et al* 2000 in their study observed that sphenoid sinus aeration began at the anterior boundary of the sphenoid bone by the age of 5 years, with patients more than 6 years old exhibiting varying degrees of aeration. The aeration on both sides continued to expand until the third decade of life. The volume decreased gradually, with the average volume in the seventh decade of life being 71% of the maximum level.[33]

Gonial Angle:-Gonial angle formed by the junction of the posterior and lower borders of the human lower jaw. Also known as angle of the jaw or angle of mandible. In infants and children gonial angle is obtuse about 140 degrees or more which reduces to 110 120 degrees in adult age and it again become obtuse about 140 degrees in old age. Izard G (1927) cited the following averages of the variability in the gonial angle: 135 to 150 degrees at birth; 135 to 140 degrees when the first dentition is finished; 120 to 130 degrees up to the time of eruption of the second molars; and 120 to 150 degrees in old age. Weinmann JP and Sicher H (1947) stated that the consecutive atrophy of the masticatory muscles in old edentulous people, after many years of increased function, leads to changes in the region of the mandibular angle.[34] Resorption of the bone at the posterior or inferior border of this region, the area of the masseter muscle insertion, leads to increasing obtuseness of the mandibular angle. Sicher H and Du Brul EL 1975 reported that after loss of all teeth, Non-denture wearers had a wider gonial angle than denture wearers.[35] Heath in 1976 concluded that the postural and

functional interrelationships of the cheek, lips and tongue in edentulous individuals can alter the gonial angle.[34]

Casey DM and Emrich LJ 1988 used panoramic radiographs and they found that the mean size of the gonial angle was 126.3 for the edentulous and 123.9 for dentate patients. Ohm E and Silness J 1999 found the mean gonial angle measurement for edentulous patients to be 131 degrees versus 127 degrees for partially dentate, without consideration of gender.[36]

Ramus height:-A line represented the ramus extended from the most superior lateral point to the most inferior lateral point on the ramus tangent. Ramus height can be measured on both sides on each panoramic radiograph. Shaw RB *et al* (2010) stated that ramus height, mandibular body height, and mandibular body length decreased significantly with age for both genders.[37] Study done by Shamout R.A 2012 *et al* observed that ramus height increased from 11-29 years then decreased with increasing age.[37] Mohite D.P *et al* 2011 observed that ramus shows an increase in dimensions with increase in age, though it is insignificant. Up to the fifth decade of life, the length of the ramus shows a gradual increase. Thereafter, the length remains more/ less constant and shows very little variation.[38]

Facial Reconstruction

Forensic facial reconstructions rely on tissue depth measurement from individuals based on gender, age, sex and nutritional state. In late 19th century Him used needles with a displaceable piece of rubber which were pushed through the flesh of his cadaver specimen at right angles to the bone. The distance and the corresponding well-defined landmark were recorded and an average of the tissue distance was calculated. Him's work was extended by Kollman and Büchly in 1898 by introducing categories of nutritional state. Since then the techniques have been developed but most of the work done has its foundation in the work done in the area in the late 19th century.[39]

Measurements using X-ray have been carried out since the 1960s (by Krogman and Iscan 1986)[40] New techniques involving ultrasound, lateral craniographs, CT and MRI have been used the last decades for the collection of thickness data (Chen *et al* 2001).[41]

Various Facial Reconstruction Techniques:

D Techniques

This method results in two-dimensional facial and profile drawings of the reconstructed face based on the measurements previously mentioned. This method is performed by drawing contours on x-rays or photos of the skull and is basically the same technique as the three-dimensional one.[42]

3D Reconstruction Using Clay Modelling

The Krogman (1986)[40] step-by-step method for clay modelling in 3D is the anatomical approach where models of all the significant muscles on the head are modelled in order to create an anatomically correct underlying structure. The muscles are then covered with a layer of clay that represents the skin. It produces results that can be very accurate, on the other hand it is extremely time consuming.

Volumetric Facial Reconstruction

Archer (1997) points out the importance of developing a computer-based system for craniofacial reconstruction and focussed on the use of parametric shapes and surfaces to describe the reconstructed face. Chen *et al* (2001)[41], a method for visualizing faces called Hierarchical Volume Deformation (HVD). The head is reconstructed from the skull with reconstruction of soft tissues.

Computed Tomographic facial reconstruction

Andersson B *et al* (2005) [43] have done a study on Digital 3D facial reconstruction on CT. Acquire data from CT, Segmentation of data, Import into software. Apply landmark dowels, Cover holes in the cranium, Perform mesh calculations, insertion of facial features, textures and render image.

Virtual Autopsy

Virtual autopsy" which was derived from the words "virtual" (Greek: virtus: effective) and "autopsy" (Greek: autos: own + opsomei: to see). The idea to conduct virtual autopsy is not new. Virtual autopsy is a type of autopsy procedure that is performed by using X-rays without mutilation of the body. This new autopsy technique consists of the internal examination of death bodies using computed tomography (CT) and magnetic resonance imaging (MRI), without opening the body or body parts. In certain cases the postmortem photographic and radiological exam is difficult because the access to the oral cavity is hindered (e.g. bodies in rigor mortis condition).In contrast to the classical dental autopsy the virtual autopsy process allows dental identification in an accurate and quick way without damaging the body to access the available dental data. Dental age estimation methods based on tooth development can be applied during the virtual autopsy, allowing the examiner to include or exclude individuals based on age related victim lists. More specific on the applications of this technology related to dental identification and associated dental age estimations.[44] Dedouit *et al* (2007)[45] stressed the importance of the presence of dentists in the forensic identification team in particular to determine the age of charred bodies. In traditional medical examinations the decomposition of the body is a limiting factor for age assessments. Oesterhelweg *et al* (2010)[46] describe a case where the victim was struck by respiratory obstruction from a foreign body (food bolus). Birngruber *et al*. (2011)[47] reported a positive identification case based on the superimposition of post-mortem CT reconstructed images on ante-mortem radiographies. Therefore, the author cites the performance of dentists to examine dental and anthropological data.

CONCLUSION

Forensic medicine is a wide subject concerning with legal aspects, consisting of various branches like forensic radiology, forensic pathology, forensic odontology etc. Forensic radiology is one of the integral branch of forensic medicine. Forensic radiology plays an important role in various criminal investigations which are helpful in determination of identity, evaluation of different injuries, various Criminal and civil cases etc. The proper communication of the Forensic dept. and Radiology dept. both can help to solve various sequels in certain genuine cases. The various modalities of radiology like

plain X-rays, CT, MRI, and ultrasonography etc. can be used depending on various forms of cases and their requirements in routine investigations as well as confirmation of various results regarding medicolegal cases, death reports etc. Forensic Radiology has wide scope in Education & Research. In India forensic radiologist concept is on the way to rise. Many projects related to forensic radiology such as age determination, postmortem examination and injury can be implement for educational and research purposes.

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