

# Maxillofacial Imaging in Forensic Science: A Newer Approach

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## ABSTRACT

Forensic science has emerged as quite interesting as well significant speciality gaining a lot of interest and importance from world of law professionals. One of the reason for its rise as a speciality is the introduction of maxillofacial imaging. The maxillofacial radiographic techniques has been found out to be quite important in human identification. Forensic maxillofacial radiology includes the conduction, interpretation, and reporting of radiological examinations and procedures connected to the courts and the law. The inclusion of the maxillofacial radiologist provides invaluable information in forensic consultations and medico legal investigations. This paper has been formulated to evaluate the role of dentomaxillofacial radiography in forensic science where radiographic methods may be used to determine identity using the teeth, root structures and frontal sinuses. Recent imaging techniques, such as computed tomography and magnetic resonance imaging are being incorporated in this speciality.

**Keywords:** Forensic science, maxillofacial radiology, forensic odontology.

## INTRODUCTION

Forensic science is a branch of scientific that include method of collection and examination of evidence in a judicial setting and is accepted by the court and the general scientific community. It is a branch of science that involves the application of dental sciences in the identification of dead individuals by comparing ante- and postmortem records.<sup>1</sup>

From 66 AD till date, identification on the basis of teeth has significantly contributed tin identification of dead individuals, the first case being accepted by the law in the year 1849.<sup>2</sup> In children, analysis of the number of teeth that has erupted play a role in the estimation of age at death, as well as, to the identification procedure of unknown skeletons. The attempt is made to compare the properties and characteristics of unknown skeletons with the person whose identity is being analyzed. So, in this manner the disappeared child can be identified. However, it also contribute in the age evaluation of living children with unknown identity, suspected of crime or violence with aggravating circumstances, by the police.<sup>3</sup>

In the 21<sup>st</sup> century despite massive advancement in science and technology, human race is still facing problems due to natural disasters (earthquakes, tsunamis), medical breakthroughs, crime, and violence accounting for the loss of numerous lives. The significance of personal identification of dead people in such situation become quite important is for personal, social, and legal purposes. Forensic science deals with the identification of the dead using numerous techniques. Forensic odontology has proved to be quite significant in human identification. Methods like rugoscopy, bite marks, palatal rugae, photographs, lip prints, etc. are used for identifying the individuals.<sup>4</sup>

Generally these methods depend solely on the examination of the soft tissues, so it become very necessary to preserve them.

This become a problem when thee body parts get burnt, lacerated and traumatized. In the human body, teeth and facial bones are hard structures and are unaffected by the decompositional/ destructional forces well even under extreme forces and/ or temperature variations. The specific anatomical features of the teeth are captured easily on the radiographs so they become an invaluable tool in forensic sciences. Radiographic identification has long been in use and the technique is efficient, comparatively easy, records can be obtained in both living and dead.<sup>5</sup> It has an added advantage that it is less expensive as compared with the DNA analysis. They can play an important role in solving the medicolegal cases with the help of sound knowledge of all these special imaging techniques which will enhance the scope of maxillofacial imaging in personal identification.<sup>6</sup>

## HISTORY

The case of dental identification was first reported in an 80-yearold John Talbot in 1453. Dr. Paul Revere is being credited as the first expert of forensic odontology. He was able to identify the body of Dr. Joseph Warren with the help of silver and ivory bridges. The earliest use of forensic odontology was used in U.S. Court. In a very interesting incident a person crime was confirmed by crushed fragments of mineral teeth fused to gold. Criminal was then hanged. L'Art Dentaire en Medicine Legale was the first dissertation on forensic odontology written by Dr. Oscar Amoedo in 1898. Since then several studies has been performed in this regard. Chantilly. Welty and Glasgow in 1946 in order to further enhance the forensic odontology introduced the use of computers and they created a computer system in which the information about the teeth of 500 people were stored in 1 minute.<sup>7,8</sup> Kieser-Nielsen assessed the uniqueness of teeth mathematically. Sogannaes et al. (1982) compared the bitemarks of twins by using computer application and found out the bitemarks were different and unique. Sweet and Pretty conducted a study to conclude that the size, shape and pattern of the incisal or biting edges of upper and lower anterior teeth are specific to an individual. Analysis of bite mark evidence through video analysis was utilized in a California court. David et al. are being credited to involve scanning electron microscopy in bite mark analysis.<sup>9</sup> In todays era of modern technology newer

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methods has been designed.

## DENTAL IDENTIFICATION PROCEDURES

The pre-mortem and post-mortem properties of a person in the teeth are unique. They can be analyzed for the purpose of forensic identification. Dental experts can examine the teeth and maxillofacial bones for the purpose of identification in trauma patients. The helpful evidence may be tooth chips, broken teeth, recent tooth loss indicating antemortem trauma to the mouth. These injuries can be attributed either as a result of non accidental or accidental trauma. By analyzing the regressive changes of teeth like attrition and other structural changes the arthropological age of the diseased person can be identified. Tooth has been used as quite reliable evidence in personal identification of living or dead persons using the specific features of the jaws and the teeth. Several researchers have advocated the uniqueness of tooth. Many scientists believe that tooth impression is more usable evidence than the bite marks, which are believed to be more specific than DNA. The genetic make-up may be same in both the twins but the dental impression may be different.<sup>10</sup>

## FRONTAL SINUS RADIOGRAPHIC ANALYSIS

### Sex Determination And Personal Identification

There are usually two frontal sinuses, located in the posterior part of the superciliary arcs. They are found to appear between the external and internal faces of the frontal bone. The anatomical features of frontal sinus include presence of septum which have the tendency to deviate from the midline. The significance of frontal sinus in forensic sex determination lies in their unique pattern. The research people strongly believe that two frontal sinus can never be same. It has been found that they are as much unique in a person as fingerprints. Even twins are considered to have different frontal sinuses.<sup>11,12</sup> Frontal sinus radiographs may be used because it is commonly exposed in sinus series investigations. It has been suggested that the frontal sinuses have the potential to be used in correctly identifying sex.

Radiographs of individuals taken by Caldwell technique with frontonasal support are evaluated. CBCT can also be used to obtain the images. It has been mentioned in several studies that frontal sinus have different patterns among males and the females. Schuller in 1943 conducted several radiological studies on morphological variations of the frontal sinus and found that

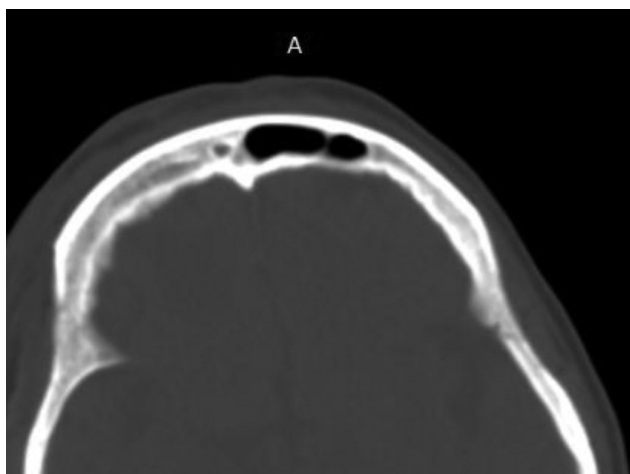


Figure-1: Frontal Sinus as observed in Axial section CBCT

the size of frontal sinus is greater in the males as compared with the females.<sup>13</sup> Ponde et al., had also given the same conclusion from his own radiological studies.<sup>14</sup> Another study showed the same result i.e the mean area of frontal sinus in males are found out to be greater than the females. Brown carried out a study and found that the sagittal diameter is more in males than in females. Similar finding was observed by Camarago et al.<sup>15</sup> However in another study it was observed that the right and the left sagittal diameters of frontal sinuses in males were greater than those for females but the differences were not statistically significant. The difference in the morphogenetic features of cranium in the males and females are quite evident. The main reason for this difference is the genetic make up irrespective of other factors like difference in nutritional status, hormonal changes and the muscular changes.<sup>16</sup> Such attributes can explain why the frontal sinus of male is larger than that of female.

## PANORAMIC RADIOGRAPHS IN AGE AND GENDER IDENTIFICATION

### Gonial Angle, Ramus Height And Bigonial Width

A significant number of studies has been performed on panoramic radiographs to measure three mandibular parameters, gonial angle, ramus height and bigonial width.<sup>17-19</sup> Some studies have shown widening of gonial angle with advancement of age.<sup>20</sup> Among the several studies conducted for measurements of landmarks on panoramic radiographs the most accurate and reliable measurable value was found out to be that of gonial angle.<sup>21</sup> Females were found to have a significant higher value of gonial angle than their male counterpart; which was similar to the results obtained by Ghosh et al.<sup>22</sup>

This study was carried out with the endeavour to establish the fact that measurable mandibular parameters in orthopantomograms such as gonial angle, bigonial width and ramus height, can be used to establish a correlation with an individual's age and gender in dentulous subjects in Far North Queensland. The study design included the involvement of the use of 2699 randomly selected panoramic radiographs of subjects belonging to the ages of 19-69 years. The analysis of each panoramic radiograph was done with the purpose of measuring and recording the above three parameters. The findings were tabulated into appropriate age and gender groups and subjected to statistical analysis.

Females, on the other hand, were shown to have a significantly larger gonial angle than males. From previous studies it can be generalized that gonial angle increases with age, whilst bigonial width and ramus height were shown to decrease with age. It was concluded that the assessment of mandibular morphology through radiographic measurements may be useful in estimating an individual's age and gender when comparing to a known population standard.<sup>23</sup>



Figure-2: Orthopantomogram showing Gonial angle and ramus height

### Demirjian's Method

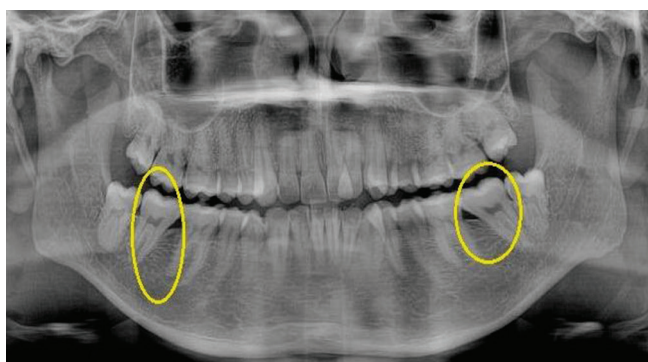
Among the various commonly used methods for age estimations on panoramic radiographs, the one that has been extensively used is Demirjian's method which is simple and practical. The advantage lies in the explanation of the stages of tooth development thereby the differences in age estimation by the different observers as by the same observer is very less.<sup>24</sup> Furthermore, it is non-invasive and can be done in-vivo. As the third molar is associated with a high incidence of congenital absence, so the modifications of Demirjian's method as suggested by Orhan et al., has been described.<sup>25</sup>

Olze et al. in their study on mineralization of wisdom teeth in Caucasian, Mongoloid and African population samples found significant differences in the reaching of a particular stage of mineralization amongst different populations, which indicate the need for population-specific investigations.<sup>26</sup>

Acharya A.B has been credited to utilize Demirjian's criteria to assess the third molar development by analysing the OPGs of 221 Indian subjects belonging to the age group of 15-21 years. He came to the conclusion that a significant one fourth population of India has been wrongly analyzed for age estimation and have been placed in wrong age groups.<sup>27,28</sup>

### Mandibular Second Molar Calcification Stages

There are two most common methods for assessment of the dental development. First one is the analysis of tooth eruption while the second one is the analysis of analysis of tooth calcification.<sup>29</sup> Since it is generally advised for orthopantomogram for patient undergoing orthodontic treatment, hence skeletal development assessment using the different calcification stages of mandibular molars will provide an added advantage over the hand wrist radiographs. If the routine radiographs will be used then there will be no added radiation exposure to the subjects. The study was conducted to investigate (1) the relationships between the stages of mandibular second molar calcification and skeletal maturity; and (2) whether second molar calcification stages can be used as a reliable diagnostic tool to determine skeletal maturity. The study design included panoramic radiographs and lateral cephalograms of 300 subjects (137 males and 163 females) belonging to age groups from 9 to 18 years. The dental maturity was evaluated using the the Demirjian Index, while the skeletal maturity was evaluated using the Cervical Maturity Index (CVMI). It can be concluded that a highly significant association exists between DI and CVMI. Mandibular second molar DI stages are reliable indicators of skeletal maturity.<sup>30</sup>



**Figure-3:** Mandibular Second Molar calcification stages on Orthopantomogram

## LATERAL CEPHALOGRAMS

### Stature Estimation For Personal Identification

Stature is unique for a person. It can be applied for personal identification when there is no complete skeleton present for analysis. In that case the stature of the remains of skeleton which is available can be used for the personal identification. It is also important to establish a method to evaluate the stature based on dead body remains obtained. It can be based on the information regarding the specificity of the population to which the dead body remains belong. For this purpose, measurements of 4 distances between cephalometric landmarks of the mandible namely Co-Co (bicondylar distance); Go-Go (bigonial distance); Co-Go (condylion-gonion distance); Go-Gn (gonion-gnathion distance) and the stature in 56 subject including both the males and females subject from Caucasian Italian population on the lateral cephalograms. It was found that the parameters were significantly correlated. This can concluded that by such measurements the stature of the mandible of a population can be found out and helpful in forensic sciences.

### MRI

Arthur Conan Doyle's fictional detective Sherlock Holmes had great interest in the fact whether the injuries were pre-mortem or the post-mortem. It is of quite important value in real forensic investigations. It is very necessary to differentiate whether the fracture is pre mortem or antimortem because it gives information regarding the sequence of events leading to the death of the patient. Then it provide information about the cause of fracture. Over the last decade, cross-sectional imaging techniques such as CT and MRI have been introduced in the practice of forensic medicine and the field of forensic radiology has evolved significantly. The main advantages of CT and MRI over ongoing procedure autopsy are the simplified and accurate maintenance of findings related to forensic. Besides these are non-invasive approach.

Another advantage of advanced forensic imaging is that they provides additional information about vital reactions. The previous literature revealed a case of a accident involving the flying activity that proved fatal. The victim got electrocuted followed by severe burning and falling from a great height. On the basis of clinical imaging findings of bone marrow oedema in acute fractures, it was concluded how the death took place that is the speed flyer death took place due to electrocution, not due to the fall and that the fractures were post-mortem in nature. In this way the sequence of events that lead to the death of the person was finalized. Here it was easy to conclude that death took place due to high power electric wire. More research is needed to find out whether oedema in bone marrow in acute fractures is a reliable significant sign.

## DIGITAL RADIOGRAPHY IN PERSONAL IDENTIFICATION

There are various methods of digital radiography present about which literature is present. The basic mechanism of image acquisition by digital radiography involve the following steps: 1) radiographic images digitization with the aid of a scanner, video camera or, yet with images acquisition directly from a x-ray machine 2) the next step involve image processing by mean of software, this feature involve comparison of images

by means of interposition or subtraction.<sup>26,27</sup> These modern techniques allow an accurate analysis of the spatial relations of teeth roots and supporting structures on ante- and post-mortem images.<sup>28</sup> Hence, without having extra exposures there can be proper comparison made between the pre-mortem and the ante-mortem images by using the digital radiography.<sup>29</sup> It has been observed that there is some wrong information provided by this technique. The main reason maybe the difference in geometry of the pre-mortem and post-mortem radiographs. The above mentioned correction is essential to remove the discrepancy in the process of image subtraction.<sup>30</sup>

## COMPUTED TOMOGRAPHY IN FORENSIC IDENTIFICATION

Three-dimensional computed tomography (CT) is a useful imaging method in the process of human identification, and presents innumerable advantages in this field as compared with the traditional radiographic projection. Firstly, there is negligible superimposition, elongation and shortening of images as compared with other modalities and there is feature of measurement of very small changes in the density.<sup>30,31</sup> CT has several advantages, such as images segmentation – an important source of information in cases which involves the evaluation of internal points. Another advantage is easy images manipulation, improved imaging quality with excellent color scale and transparency as well as information regarding measurement of volume and area as well as both angular and linear measurements. With the help of antemortem CT image the post mortem image can be created using the added advantage considering that craniometric points can be precisely located and measurements can be accurately performed. Besides, the film provide information regarding with the positioning of the patient, angulation, slice thickness, kV, exposure time, size of the visual field, etc. There are other details about the patient such as name, age and sex of the patient on the film. The CT film has also information like that name of the assisting physician, hospital, and other relevant information.

## CBCT IN AGE ESTIMATION

There are number of methods for age estimation using the teeth. The most accurate method is analysis of dentin apposition. This apposition is a continuous, age-associated process, which alters the size of the pulp chamber. It can be affected by the pathological conditions like caries. There has been use of several methods in order to assess the volume of pulp chamber giving information about the secondary dentin apposition. These methods include cross sections of the teeth as well as taking radiographs. Both panoramic and periapical radiographs have been used to assess the pulp/tooth area ratio of maxillary canines. The major disadvantage of radiographs is that they are two-dimensional projections and do not give information regarding volume which is three dimensional entity. Therefore, the buccolingual analysis should be carried along with the mesiodistal measurements. Cone beam Computed tomography (CBCT) is one of the most reliable method for this purpose.

## CBCT IN FACIAL RECONSTRUCTION

The soft tissue details can be obtained from the skeletal remains of the dead body. This method of regenerating the face of the dead person from the skeletal remains is known as the

facial reconstruction. The concept of the facial reconstruction belong to the branch of anthropology. Moreover this concept is quite useful in forensic identification. The concept of facial reconstruction is as old as ancient history in Europe where the clay artists used to reconstruct the face of the dead person by putting clay according to the facial contours on the skeleton. In order to achieve accurate details several methods has been introduced to digitize the method of facial reconstruction. CBCT is one of the most reliable method in this regard. The initial technology which was used to digitize the details of the skull was Laser technology. The details provided by the CBCT images of the skull of the dead person are very fine details in all three planes. With the help of such fine details and computer software pre-mortem face of the person can be recreated. Cone-beam computed tomography commonly used in dentistry that can produce higher resolution in digitization of the skull while producing lower levels of radiation. Several studies are being carried out to further increase the utilization of CBCT in this field.

## CONCLUSION

Over the last decade, the importance and valaibility of forensic science has taken a giant leap. This can be attributed to the introduction of maxillofacial imaging in forensics. The newer modality of CT and MRI introduction and their effective utilization in these condition. MR is the favored imaging modality for non-forensic post-mortem imaging and is mainly used to analyze non-traumatic findings. The primary focus in forensic imaging is on traumatic findings, with extra importance on the analysis regarding gunshot injuries. There are very few studies oriented towards imaging findings of drug abuse and intoxication, despite of their considerable contribution to the case load of forensic investigations. The recent research indicates that radiology is becoming an invaluable tool in post-mortem investigations, whether they are performed in the course of forensic investigation, or during hospital-based morbidity / mortality review. Research efforts in this field are conducted worldwide and forensic radiology may indeed emerge as a distinct subspecialty of forensic medicine and radiology.

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