Review Article

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Forensic outlook of Maxillofacial Radiology : An inevitable tool revisited

Abstract: Radiology has a wide range of application in the field of forensic dentistry and has set many benchmarks over decades. The purpose of this paper is to revisit the applications where radiographic methods may be used to determine the identity. Age and gender determination, craniofacial reconstruction, mass disasters, trauma and abuse and virtopsy has been reviewed in this paper with focus on two dimensional and three dimensional imaging modalities highlighting the recent advancements incorporated in these techniques. The radiologists' play a pivotal role in cases of civil litigation and fraud. There are gaps to be bridged between forensic speciality and maxillofacial imaging. Henceforth, this article offers several suggestions for possible research projects to close some of these gaps.

Key-words: Radiography, Dental; Forensic Dentistry / methods; Diagnostic Imaging.

Introduction:

Forensic odontology is a significant outgrowth of forensic medicinal sciences and, in the felicity of justice, pacts with the apt examination, handling and demonstration of dental evidence in the court of law. It plays a pivotal role in identifying the human remains of victims, not only those of mutilated, burnt and decomposed but also victims of bioterrorism and mass disasters.[1]

Over the last decade the importance and valuability of forensic science has taken a giant leap. Maxillofacial Radiography is an integral branch of forensic odontology. It has become a routine procedure in dental/medical hospitals and clinics in the current scenario. It is used for comparative recognition, which attempts at conclusive identification by comparing the radiographic record of deceased individual.[2] Radiographs shed light on many issues both in determining the current situation and in comparisons with the past. It is also useful in reconstructive identification or dental profiling, attempts in facial reconstruction techniques to elicit the lost identity of an individual.[2] (Figure 1)

Figure 1: Applications of Maxillofacial Radiology in Forensic Dentistry.

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Person and dental identification:

The usefulness of radiographs in post mortem examination has been illustrated by David and Paul, who described radiographs help in post-mortem dental identifications by locating and identifying anatomical structures, dental restorations, dental appliances, required in the comparison process. Radiographs play an exclusive role in severe mutilated cases such as burn victims where complete tissue destruction has occurred and DNA analysis becomes impossible.[3]

Traditionally, two dimensional (2D) radiographs of frontal sinus, bite-wing radiographs were considered as an efficient tool for dental identification.[2,3] However, Digital radiographic techniques such as Radio-visiography (RVG) allow accurate analysis of the spatial relations of teeth roots and supporting structures on antemortem(AM) and post-mortem(PM) images.[4]

Recently, Dental Profiling is used to recreate the victim's profile prior to death, based on the accessible clinical and radiological data.[3]

With the advent of three dimensional (3D) imaging techniques, the ante-mortem CT image can be utilized in profiling of the postmortem images, which allows accurate location and measurement of the cranio-metric points.[4] Also, CBCT is currently used for post-mortem imaging and for imaging high-density metal projectiles in cases of gunshot injury in forensic odontology.[2]

Mass disasters:

In mass disaster incidents, radiographs are often made on location using portable dental X-ray unit. Full mouth radiographs are preferred to cover all fragments which are digitized through computer, for rapid comparison.[5] More recently a 2D automated recognition technology allows cross matching of a pool of radiographs of suspected victims against radiographs of PM remnants and eventually it enables the content-based retrieval of AM images that match to PM images.[6] The use of Computer- Assisted PM Imaging (CAMPI) for such comparisons holds record of successful use in many cases in the past.[4]

Mobile CT scanners are efficiently used in mass fatality disasters. These scanners can be used in and outside permanent and temporary mortuaries.[7] The use of high resolution eLU-CT minimizes the production of metallic artifacts caused by dental fillings. Semi-automated image analysis software also have been developed to perform such comparisons.[7] CBCT images are reconstructed from one scan and it facilitates the operator to select any desirable slice location -and orientation. CBCT also minimizes the production of artifacts and errors in victim identification.[4] Fluoroscopy is also used to scan the bodies of disaster victims and it scan these bodies at first reception stage followed by further or plain x-ray examination.[8] The use of MRI in both permanent and temporary mortuaries depends upon the availability of fixed and mobile technologies and are sensitive to the type of specimen to be scanned as bodies or body parts containing metallic material are difficult to scan with MRI.[8]

Recently the introduction of 'Dental biometrics' utilizes dental radiographs for identification of deceased individuals. It extracts dental or tooth segment from mixture of Gaussian models and later allows matching of images, computation of image distances and subject identification.[7]

Age estimation:

Maxillofacial imaging for forensic age estimation in living adolescents and young adults continues to be controversial and a subject of discussion. Pre-natal, neonatal and post-natal age determination is done by radiographic examination of Jaw bones pre-natally and evaluating tooth germs which are present before mineralization in intrauterine life and are visualized as radiolucent areas on radiographs prior to mineralization.[9] Methods of age estimation such as Kraus and Jordan's technique, Schour & Masseler method, Mooree's, method, Demirjian's method Nolla's technique, Kvaal's method, Harris and Nortje method, Van Heerden method have been well established techniques used for a long period.[9] Morphology of gonial angle, ramus height and bigonial width, size of the skull using cephalometry are well established methods in the court of law.[10] Radiological studies on development of sinus and its usefulness for chronological assessment have been conducted in the past.[11]

Occurrence of hyperostosis in post-menopausal females and decrease in size of frontal sinuses in old females, ossification points analysis such as Spheno-occipital synchondrosis and Cranial base synchondroses are useful markers to assess age on radiographs.[12]

Application of CBCT for assessment of Pulp Tooth Ratio is widely accepted for age estimation. This ratio significantly decreases with advancing age due to secondary dentin deposition on pulpal walls.[7]

Gender Determination:

Human beings demonstrates diverse sexual dimorphism exhibited by the craniofacial frame which aids in this process and can be easily identified on both analog and digital 2D radiographs by analyzing linear and angular measurements of dental arches with an acceptable accuracy rate.[13]

Teeth measurements on panoramic radiographs, lateral cephalometric radiography, postero-anterior projections have proven to provide with 80% accuracy in gender identification.[14] These radiographs facilitates the measurement of the total tooth, crown, root length of all teeth, bony ridges, crests, and processes including temporal line, mastoid processes, nuchal lines, external occipital protuberance, and superciliary arches, total craniofacial height, mastoid height, bicondylar width, and mandibular width in one frame.[14] CBCT analysis of frontal sinus (FS), Maxillary Sinus (MS), Foramen Magnum (FM) is considered as a powerful parameter for Gender determination and provides highly accurate results.[8] It allows analysis of mandible showing significant dimorphic trait of the mandible in its shape and size. The linear measurement of the ramus on CBCT is found to be greater in males compared to females. The gonial angle however, is found to have downward and backward rotation in mandible in females while in males it has only forward rotation.[8] Assessment of foramen magnum (FM) on CBCT reveals higher measurements in males.[8]

Identification of trauma and abuse:

Maxillofacial Imaging assist investigators in matters related to the law by encompassing the evaluation and documentation of abuse/ injury or cause of death.[15] Bite marks analysis of cases involving sexual assault, murder and child abuse can be accomplished using Maxillofacial Imaging.[16]

Radiographic wax impression technique, Xeroradiography, Contrast enhanced radiography and CBCT may also provide valuable information and aid in standard procedures of identification by generating overlays for bite mark analysis. [17,18]

Implementation of dental radiographs are useful as a forensic evidence is used to assess traumatic injuries such as fractures of skull or concerning the dentoalveolar region, tooth avulsion and tansposition which are usually non-accidental in cases of Child abuse, domestic violence.[19] MRI and CT are also used to assess this soft and hard tissue injuries.[20]

Facial reconstruction:

Craniofacial reconstruction (CFR) is a technique that replicates the individual facial characteristics, published using media and therefore lead to recognition identification of the unknown.[10] Multiple 2D and 3D imaging modalities are available nowadays that enables CFR.[21]

Pseudo-three-dimensional radiography and computer aided lateral cephalograms are used nowadays for CFR.[21] Ultrasound has been employed in CFR which allows the qualitative and quantitative assessment of various soft tissues.[21]

3D computerized reconstruction technologies (3D-CT) employ multiple imaging technologies for forensic identification. 3D-CT features many advanced tools for reconstruction and generation of greater quality images.[21] MRI accurately determines soft-tissue depths, including elucidation of finer structural features.[10] Various CBCT softwares provide 3D imaging of the skull using lower levels of radiation, thereby aiding in this process.[10] Application of Maxillofacial radiology in CFR has recently incorporated technological advancements such as Fusion Imaging which combines CT scans and 3D facial images through optical method; Laser scanners which are non contact surface imaging modality and allow generation of image after a 360 degree rotation and Digital stereophotogrammetry which is a non-invasive method with fast scanning time, that furnishes real-like appearance of an individual with accurate geometry refined colour and texture.[21]

Maxillofacial Imaging in Virtual Autopsy:

Virtopsy is a noninvasive procedure of autopsy elaborated with advanced tools for analysis and combined with 3D body

surface imaging methods. It uses CT/MRI data and performs 3D shape analysis.[22] Post mortem CT datasets allows evaluation of putrefied or massively damaged bodies after detailed evaluation of the hard tissue framework in multiple sections.[22] MRI enables the visualization of soft-tissue organs while Contrast based MRI allows examination of living victims of abuse, such as manual strangulation.[23] MR Spectroscopy is useful in estimation of the time of death by determining relative concentration of metabolites in tissues. MR microscopy is another tool that allows "micro-imaging" to visualize finer soft-tissue injuries and "micro-tomography" which allows analyzing the weapon involved and resultant injury patterns.[24] In the era of Artificial Intelligence, Maxillofacial Radiology is applied in robotic methods for Virtopsy which is known as "Virtobot". It accommodates modules for automatic surface scanning and minimally invasive biopsies[22]

Recent advances of maxillofacial imaging in forensic sciences:

Growth and Progress of Forensic dentistry has propelled responsibilities and role of Maxillofacial Radiologists towards this sub speciality of Forensic Science, at a global scale.[25] 3D printing has a myriad of applications in forensics by means of 3D bite mark analysis, 3D skull printing which is done for comparison with dentition of the suspect and analysis of trauma respectively. Softwares like Computer-Aided Design (CAD) in Standard Tessellation Language (STL) formats from CT and CBCT and Additive Manufacturing Format (AMF) from laboratory optical surface scan, allow incorporation of additional features like color, texture, and material properties supporting forensic identification.[26]

Conclusion:

"Forensic Maxillofacial Radiology", has become an important tool in the field of forensic odontology and has aided forensic odontologists a numerous times in the investigation process. The contribution of Maxillofacial Radiology today is an "absolute witness", of the development of the field of Forensic Maxillofacial Imaging. Thus, the credentials attained by Maxillofacial Radiology have scored many stars at an universal level in the forensic space. Nevertheless, it will be incomplete to conclude without pointing out the fact that, the "spectrum of rays" has crossed many multitudes in the field of forensics and with advanced imaging modalities venturing over the years, a paradigm shift in the forensic world has been created by Maxillofacial Radiology.

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