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The Role of *Cone Beam Computed Tomographic* (CBCT) in Odontology Forensic for Forensic Identification

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Abstract
Cone Beam Computed Tomography (CBCT) is a significant technological advancement in maxillofacial imaging, providing a three-dimensional radiograph that can display the anatomical structure of the jaw bone and face in axial cut or view coronal and sagittal. The main advantage of this technique is that it is a non-invasive method without jaw resection as we have only one scan to be compared with several types of radiographs including panoramic, periapical, and lateral cephalometry. CBCT is popular in dentistry and is increasingly used in forensic cases due to its advantages for antemortem and post-mortem data, including good resolution, portability, and simplicity. CBCT radiography is an important part of forensic odontology because it can support the process of forensic identification of both living and dead through a comparison of antemortem and postmortem data. The use of CBCT radiography is not only for individual identification, but it can also be used to determine the cause of death and predict age, gender, and even ethnic groups. CBCT can also be used as evidence acceptable in the justice system, making it important in forensic identification and medicolegal cases. This current review is an overview of the role of CBCT in odontology forensics especially for identification forensics.

Keywords:
CBCT; Odontology Forensic; Forensic Identification.

1. INTRODUCTION

CBCT provides highly detailed, three-dimensional images of the maxillofacial region with a lower radiation dose than conventional computed tomography (CT). This makes CBCT an ideal tool for post-mortem imaging and identification of victims, especially in cases of carbonized or fragmented remains. The superior image quality and accuracy of CBCT have been particularly beneficial in various forensic applications. CBCT has been used to analyze the relationship between skeletal structures, such as the nasal bone and external nose morphology, for facial recognition and identification (1). Additionally, CBCT has been employed to study the dimensions and morphology of anatomical structures like the maxillary sinus, foramen magnum, and clivus, which can provide valuable information for age and sex estimation [2]. CBCT has been utilized in the analysis of bite marks on food items, providing a three-dimensional reconstruction of the bite pattern for forensic identification purposes. The prevalence of

CBCT in forensic odontology for forensic identification is well-documented in the literature. The superior imaging capabilities, lower radiation exposure, and versatility of CBCT have made it an invaluable tool in various forensic applications, including post-mortem identification, age and sex estimation, and bite mark analysis [1].

Identification is a way to identify individuals by utilizing characteristics and traits to distinguish them from other people, whether dead victims, living victims, or skeletons. This identification process is important because it involves medicolegal and human rights aspects. Forensic identification examination is an examination that is carried out for the first time when a disaster occurs. Non-criminal cases such as war, natural disasters, and accidents, as well as cases of paternity (determining the biological father), as well as criminal cases with unknown victims, require forensic identification [3]. Identification of deceased victims is carried out to fulfill the rights of victims so that they can be returned to their families and properly buried according to their beliefs during their lifetime [3,4]. Identification methods in forensics are divided into two types, namely primary identification methods and secondary identification methods. The primary identification method is globally viable and has proven to be the most effective identification method. The primary identification method uses fingerprints, teeth, and DNA. The secondary identification method is an identification that is less specific and does not have a high level of accuracy compared to the primary identification method, for example, secondary identification is an identification method that is carried out using clothing, jewelry, documents, and passports, considering these things at the time of the incident. Mass disasters can be separated and separated from the owner so that the goods are only as a support [5,6].

Forensic odontology is a science that applies the science of teeth as a means of evidence for the benefit of the judiciary and law enforcement. One aspect of its scope is its role in assisting the forensic medical service function in handling cases that require identification with dental facilities. One key aspect of identification in forensic odontology is radiology [7]. Dental radiology provides radiographic images of dental anatomy, which are used to compare dental charts or written records, making identifying victims easier than solely relying on antemortem and postmortem information [8].

Cone Beam Computed Tomography (CBCT) imaging represents the most significant technological advancement. CBCT is a groundbreaking innovation that is extensively utilized in maxillofacial imaging across all dental specialties, including orthodontics, endodontics, oral surgery/pathology, periodontics, and implant treatment planning. Radiographs play a critical role in forensic investigations, providing objective documentation of anatomical conditions and prior dental care. The introduction of CBCT in maxillofacial 3D imaging has greatly benefited forensic science, aiding in age estimation through teeth, bite mark analysis, determination of race and sex, etc. Its benefits, including imaging accuracy, digitized technology for easier comparison, long-term record storage, cost efficiency, dose reduction, and better portability, have made it essential in forensic identification (9). The prevalence of CBCT in forensic odontology is also underscored by its application in post-mortem imaging, where it serves as a complementary tool to traditional autopsy methods. For example, CBCT has been

utilized to evaluate the maxillary sinus dimensions, which can provide valuable information for sex determination in forensic contexts [10]. The role of CBCT in forensic odontology for the identification process is very important. We will discuss the role of CBCT in the forensic identification process.

2. RESEARCH METHODS

This literature review explores the role of Cone Beam Computed Tomography (CBCT) in forensic odontology for forensic identification by analyzing relevant studies published between 2013 and 2024. The sources were collected from electronic databases, including PubMed, Scopus, and Google Scholar, using keywords such as "CBCT," "forensic odontology," "dental identification," "age estimation," and "trauma analysis." Inclusion criteria were studies focusing on CBCT applications in postmortem identification, age estimation, trauma assessment, and forensic anthropology. Exclusion criteria included articles unrelated to forensic identification, studies using alternative imaging techniques, and non-English publications. The selected studies were critically analyzed to evaluate the accuracy, reliability, and advantages of CBCT compared to conventional imaging methods, as well as its practical implications and limitations in forensic investigations. Data were synthesized to provide a comprehensive overview of CBCT's role in enhancing identification accuracy in forensic odontology.

3. RESULT AND DISCUSION

3.1.Cone-Beam Computed Tomography (CBCT)

Since the advent of the X-ray, dental radiology has emerged as an essential diagnostic instrument that enhances the clinical evaluation of dental patients, facilitates treatment planning, and assists in the prognosis of dental conditions. Intraoral and standard radiographic techniques face challenges due to their two-dimensional (2D) projections, which can lead to problems such as magnification, distortion, overlapping images, and inaccurate representation of structures. Cone-beam computed tomography (CBCT) offers a distinct alternative to traditional computed tomography (CT) and has seen a rise in acceptance in dentistry over the past five years, as it produces three-dimensional (3D) images with lower radiation exposure and cost, as well as better spatial resolution than conventional methods. CT [11].

CBCT has transformed maxillofacial imaging through its extensive applications in dentistry, from diagnosis to treatment planning. Early CBCT systems utilized image intensifiers with large fields of view (FOVs), which resulted in higher radiation exposure for patients, although these levels remained lower than those of medical CT. Recently, advancements in software have refined CBCT scanners with enhancements that decrease radiation doses, such as using a small FOV, employing pulsed radiation exposure, and incorporating collimation. Additionally, the use of CBCT should be clinically justified for each patient, adhering to the principle of keeping radiation doses “as low as reasonably achievable (ALARA),” as recommended by the ADA [11].

3.2.Forensic Identification and Odontology Forensic

Identification is a way to identify individuals by utilizing traits and characteristics to distinguish them from other people, whether dead victims, living victims, or skeletons. This identification process is important because it involves

medicolegal and human rights aspects. Forensic identification is the determination of the identity of someone to assist investigators in proving criminal law cases and civil law. Defining identity personally correctly is very important in the investigation to assist the judicial process [4]. Identification checks can use biological methods such as odontology (teeth), DNA (Deoxyribonucleic Acid), fingerprint, blood type, and anthropology (body characteristics). Identification methods in the forensic world are divided into two types, namely primary identification methods and secondary identification methods. The primary identification method is globally viable and has proven to be the most effective identification method. The primary identification method uses fingerprints, teeth, and DNA (Deoxyribonucleic Acid). The secondary identification method is an identification that is less specific and does not have a high level of accuracy compared to the primary identification method, for example, secondary identification is an identification method that is carried out using clothing, jewelry, documents, passports, considering these things at the time of the incident (5,6).

Forensic odontology is a science that applies the science of teeth as a means of evidence for the benefit of the judiciary and law enforcement. One aspect of its scope is its role in assisting the function of forensic medicine in handling cases that require dental identification. One of the methods of identification using teeth is by comparing postmortem data (the results of the victim's examination after death) and antemortem data (previous dental data that the victim had made while still alive). By comparing this, it can give results at the individual level, which is to know the identity of the identified person. If the results of the comparison are the same, then the identification result is positive, which means that the victim being examined is the same as the person estimated. On the other hand, if the identification result is negative, then the victim is not the person who is expected so other dental data are needed to be compared. Antemortem data can be in the form of dental records (dental medical records or written information about the condition of the teeth during dental examination, treatment, or dental care), dental x-rays, dental impressions, dental prostheses or dentures, orthodontic appliances (dental brackets), facial photographs or photographs. Profile of the teeth and mouth area [5,7].

3.3.Role of CBCT in Forensic Identification

CBCT has found widespread use in dentistry for clinical purposes. Its application for imaging both hard and soft tissues in the body, especially the facial bones and teeth, allows for the production of detailed three-dimensional images. In the context of corpse identification, Postmortem Computed Tomography (PMCT) offers the advantage of triaging corpse bags, and facilitating examinations without the need to open the bags, which provides insights into the dental condition of the deceased. Another advantage of the CBCT system is its user-friendly operation, requiring minimal space for setup. The safety measures necessary for using CBCT are relatively low compared to other imaging techniques. Additionally, the installation of CBCT does not require specialized infrastructure, and the initial configuration is simple and easy, particularly for systems that can be readily disassembled and reassembled. Within the operating room, the unit can be easily stored and arranged according to the available space. Only a brief training period is needed to operate this equipment, as it is tailored for specific

functions. In almost all clinical situations, to reduce the reliance on specialized radiology operators, either an assistant or a physician usually manages the device. This aspect also contributes to cost savings for the clinic (8).

The application of Cone Beam Computed Tomography (CBCT) in forensic odontology has garnered increasing attention in recent years, highlighting its utility in various forensic processes. CBCT is a three-dimensional imaging technique that provides detailed visualizations of dental and maxillofacial structures, making it particularly advantageous for forensic identification and analysis. Its non-invasive nature and lower radiation exposure compared to traditional computed tomography (CT) further enhance its appeal in forensic contexts [1].

Figure 1. Cone Beam Computed Tomography (CBCT) A) Seated (e.g., 3D Accuitomo 170, J Morita Corp., Osaka, Japan). (B) (e.g., X-Mind trium Pan 3D, Acteon North America, Mt. Laurel, NJ) and (C) (e.g. Rayscan Alpha 3D, LED Medical Diagnostics Inc., Atlanta, GA), Standing. (D) Supine (e.g., Newtom 5G, QR srl, Verona, Italy) [15].

Recent studies have demonstrated that CBCT can significantly aid in human identification through the analysis of dental structures. For instance, Franco et al. emphasized the effectiveness of CBCT scans in registering dental identifiers, which are crucial for human identification, especially in disaster victim identification scenarios [12] The INTERPOL guidelines for disaster victim identification often incorporate such imaging techniques to ensure standardized and effective identification processes [12]. Furthermore, CBCT has been shown to facilitate age estimation and sex determination through the analysis of maxillary sinus dimensions and other craniofacial features. This capability is particularly valuable in forensic odontology, where establishing the identity of unknown individuals is paramount [13].

Moreover, the application of CBCT extends to bite mark analysis, where its three-dimensional imaging capabilities allow for a more accurate representation of bite patterns compared to traditional two-dimensional methods. This advancement is crucial, as accurate bite mark analysis can provide significant evidence in legal cases involving assaults or homicides. The ability to visualize and analyze bite marks in three dimensions helps forensic odontologists avoid the distortions and loss of information that can occur with conventional imaging techniques [14].

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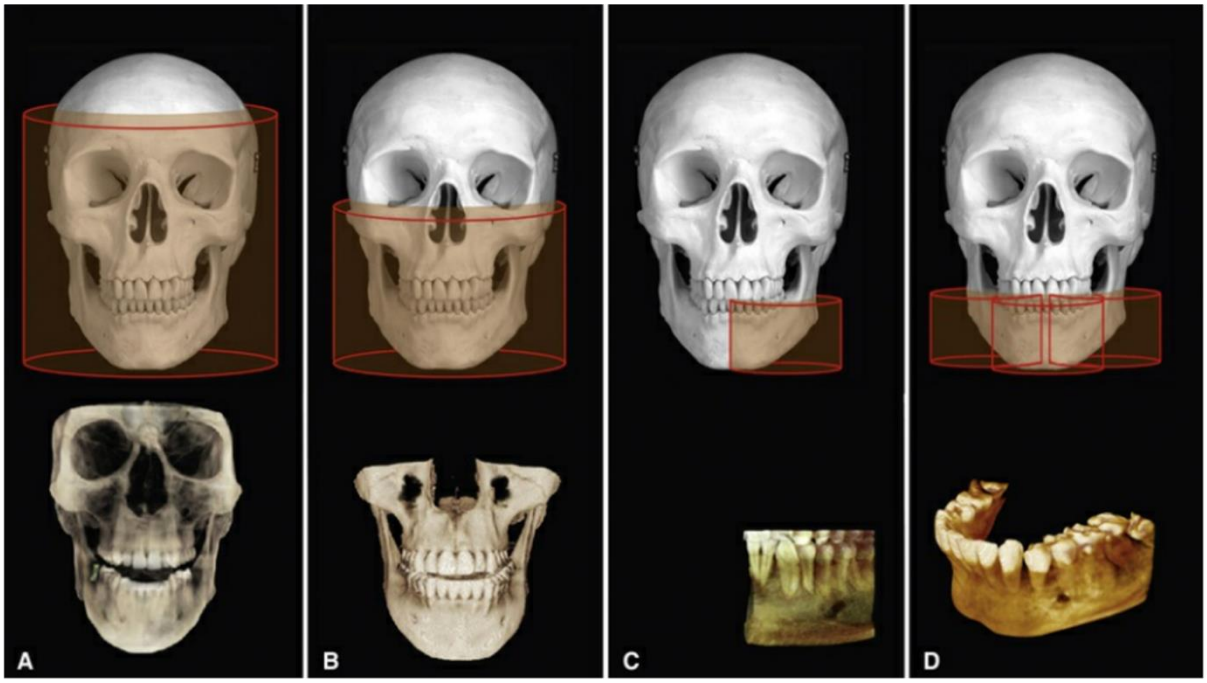

Figure 2. Classification of Cone Beam Computed Tomography Units According to the Field of View (FOV). (A) Large FOV scans provide images of the entire craniofacial skeleton, enabling cephalometric analysis. (B) Medium FOV scans the image of the maxilla mandible or both. (C) Focused or restricted FOV scans provide high-resolution images of limited regions. (D) Stitched scans from multiple focused FOV scans provide larger regions of interest to be imaged from the superimposition of multiple scans [15].

This capability is particularly valuable in forensic odontology, where establishing the identity of unknown individuals is paramount. Moreover, the application of CBCT extends to bite mark analysis, where its three-dimensional imaging capabilities allow for a more accurate representation of bite patterns compared to traditional two-dimensional methods. This advancement is crucial, as accurate bite mark. Analysis can provide significant evidence in legal cases involving assaults or homicides. The ability to visualize and analyze bite marks in three dimensions helps forensic odontologists avoid the distortions and loss of information that can occur with conventional imaging techniques [13].

Despite its advantages, the integration of CBCT into forensic odontology is still evolving. While it is increasingly recognized as a valuable tool, some researchers have noted that there remains a need for further validation of its applications in forensic contexts [1]. The scientific community continues to explore the full potential of CBCT, particularly in enhancing the accuracy and reliability of forensic analyses. As the technology matures, it is expected that CBCT will become a standard component of forensic odontology practices, complementing traditional methods and improving overall forensic investigations. In summary, CBCT is not a new technology; rather, it has been progressively adopted in forensic odontology due to its numerous advantages over traditional imaging methods. Its applications in human identification, age estimation, sex determination, and bite mark analysis underscore its growing importance in forensic science [1].

4. CONCLUSION

Cone beam computed tomography (CBCT) imaging is the most significant technological tool. CBCT which has been used in dental practice also has a role in the

field of forensic odontology to assist the identification process. The use of CBCT radiography is not only for individual identification, but it can also be used to determine the cause of death, and predict age, gender, and even ethnic groups. In addition to identification, CBCT can be used as evidence acceptable in the justice system so that it plays an role important in forensic identification and various cases medicolegal. They are useful because of the easy, simple, and fast mode of obtaining information in a non-destructive way. In addition, radiography is considered more economical compared to DNA technology.

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