



Applications of Imaging in Forensic Odontology: Pathway towards justice through Dentistry

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ABSTRACT

Establishing the personal identity of an individual holds a major role in forensic and is usually compared with known features to unknown specimen. It plays a vital role in medico-legal cases in the identification of a person. The human skulls of an individual are revival source for identifying victims or suspects in forensic odontology. The morphological configuration of mandible, foramen magnum, maxillary sinus and other features help in gender/sex determination of an individual. Forensic radiology and forensic imaging play an important role in identifying the individual. In the last few years, forensic odontology has been challenging field within the forensic sciences and enabling the recognition of diseased individual. So, this paper highlights the various aspects of imaging that help in forensic odontology.

Keywords: CBCT, forensic odontology, 3D, forensic investigation, Ante-mortem, Post-mortem

Introduction

Advanced imaging provides a platform for 3D visualization; image manipulation; applications of various software available adding boon; and interpretation of lesions. CBCT is also known as the 3rd eye in dentistry. Forensic odontology uses functional, physical, normal, or pathological characteristics to establish the identity of the unidentified and deceased as its major role. Cone-beam computed tomography (CBCT) has emerged as a transformative tool in forensic odontology, providing detailed three-dimensional imaging that enhances the accuracy and efficiency of forensic investigations. Traditional two-dimensional radiographic methods, while valuable, often present limitations in terms of superimposition and distortion, which can hinder precise analysis in forensic contexts. CBCT overcomes these challenges by offering isotropic resolution and volumetric imaging, enabling comprehensive visualization of craniofacial structures.¹ 2D images can help in investigations of underwood septa, nasal septum patterns, etc.¹⁵

One of the primary applications of CBCT in forensic odontology is human identification. The technology facilitates the comparison of Ante-mortem and Post-mortem dental records, allowing forensic experts to match unique dental features with high precision. This is particularly useful in mass disaster scenarios, where rapid and accurate identification is critical.² Additionally, CBCT

aids in age estimation by providing detailed views of dental development and pulp chamber morphology, contributing to the estimation of chronological age in both living and deceased individuals.³

CBCT also plays a pivotal role in analysing trauma and pathological conditions in forensic cases. The high-resolution images enable the detection of minute fractures, foreign objects, and bone lesions that might not be visible through conventional imaging techniques. This enhances the ability to reconstruct events leading to injury or death, thus supporting legal investigations.⁴

Furthermore, CBCT's non-invasive nature and relatively low radiation dose compared to traditional CT scans make it a preferred choice for forensic applications. It allows for the preservation of forensic evidence while minimizing the risk of damaging delicate remains.⁵ As forensic odontology continues to evolve, the integration of CBCT is expected to expand, further solidifying its role as an indispensable tool in the pursuit of justice.

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Historical background

- Roentgen (1895) discovered X-rays. Dr. Otto Walkhoff, in 1896 first dental radiograph.
- Sir. Godfrey N. Hounsfield, developed the prototype scanner in 1970.
- In 1980 electron beam CT was introduced by Andrew Castagnini.
- Radio Visio Graph (RVG), was invented by Dr. Frances Mouyens and manufactured by Trophy Radiology (Vincennes, France) in 1987.
- The first CBCT scanner was developed by Italians and Japanese in 1990.⁶

Benefits of CBCT

- 90% less radiation exposure as compared to CT scans.⁶
- Quick procedure and painless.
- No discomfort to the patient.

CBCT sections

There are various CBCT sections namely-

1. Axial section
2. Coronal section
3. Sagittal section
4. 3D reconstruction

USES OF CBCT

CBCT is the solution to the need for more precise diagnostic tools in dental implantology, orthodontics, and endodontics. The technology's ability to capture high-resolution images with a single rotation around the patient made it superior to conventional radiography and reduced the radiation dose compared to full medical CT scans.⁷ Over time, improvements in software and hardware have led to faster image acquisition, enhanced resolution, and expanded applications in both dental and forensic fields.⁵

As CBCT technology evolved, its role extended beyond routine dental diagnostics to forensic odontology, where it became instrumental in age estimation, human identification, and trauma analysis. Today, CBCT continues to play a critical role in advancing forensic investigations by providing non-invasive, detailed imaging that preserves evidence and aids in the reconstruction of complex cases.

Uses of CBCT in Forensic Odontology:

1. **Human Identification:** CBCT plays a crucial role in forensic identification by enabling the comparison of ante-mortem and post-mortem dental records. Its ability to capture high-resolution three-dimensional images

allows forensic experts to identify unique dental features, such as restorations, root canal treatments, and dental anomalies. This technique is particularly valuable in mass casualty incidents and cases of decomposed or fragmented remains.²

2. **Age Estimation:** Age estimation is a fundamental aspect of forensic odontology, and CBCT provides detailed visualization of dental development, pulp chamber size, and the degree of third molar eruption. The volumetric data obtained through CBCT facilitates more accurate age estimation, which is essential in both living individuals (for legal age assessments) and deceased persons.³
3. **Trauma Analysis and Injury Assessment:** CBCT aids in the detection and analysis of craniofacial trauma, including fractures, dislocations, and bone defects. The high-resolution imaging helps forensic experts assess the extent of injuries and identify patterns consistent with specific types of traumas. This information is invaluable in reconstructing the events leading to injury or death.⁴
4. **Bite Mark Analysis:** CBCT offers enhanced visualization of soft and hard tissues, making it useful for bite mark analysis. By providing three-dimensional reconstructions of bite marks, forensic odontologists can compare them with dental impressions from suspects, improving the accuracy of matching and reducing errors associated with traditional two-dimensional imaging.⁵
5. **Pathological Evaluation:** CBCT enables the identification of pathological conditions, such as cysts, tumours, and bone lesions, which may provide critical evidence in forensic cases. The ability to detect minute abnormalities aids in the assessment of disease-related deaths and underlying health conditions.⁵
6. **Airway and Sinus Analysis:** In forensic investigations, the assessment of airways and paranasal sinuses can provide insights into causes of death, particularly in cases involving asphyxiation or sinus-related pathologies. CBCT's detailed imaging of these structures enhances the forensic expert's ability to identify abnormalities that may contribute to death.¹
7. **Facial Reconstruction:** CBCT data can be used to digitally reconstruct facial features by providing detailed images of the craniofacial skeleton. This application is particularly valuable in forensic



anthropology and cases involving unidentified remains, where facial reconstruction may assist in public identification efforts.²

8. Age estimation: can be done by-

- Coronal tooth-pulp ratio
- Spheno-occipital synchondrosis

9. Gender determination can be done by-

- Measurements of ramus of mandible
- Foramen magnum
- Frontal sinus
- Orbit
- Maxillary sinus
- Mastoid process

10. Personal identification can be done by-

- Nasal septum patterns
- Implant back tracing

CBCT's diverse applications in forensic odontology make it an indispensable tool for modern forensic investigations. Its ability to produce detailed, non-invasive, and accurate imaging continues to advance the field, contributing to more efficient and reliable forensic analyses.

Role of Radiographs in Forensic Dentistry

Radiographs play a key role in forensic investigation as they are the best way to provide objective evidence of the anatomical conditions and the dental treatments. They are beneficial due to their ease, simplicity, and quick modes of obtaining information in a non-destructive manner. Furthermore, they are economical in comparison to DNA technology.^{8,9}

Dental identification is achieved by comparing the AM and PM radiographs of dental and maxillofacial structures and determining the concordant points for positive or possible identification.⁸ CBCT generates panoramic image as compared to multi slice CT as well as MRI. The advantage of CBCT over multi slice CT and MRI is that the result obtained is more precise, it can give CT scan of single tooth evaluation as well as detailed panoramic image skull volumes. The disadvantage is the metal artifacts imaging. Radiation dose, when compared to multi-slice CT, is very low (19-368 micro Sv 20 s scan 68miccroS). The spatial resolution of CBCT in "best possible" experimental scenario of <math><31\text{p mm}^{-1}</math> with a median value of approximately .¹⁰⁻¹⁴

Discussion

Imaging plays a pivotal role in modern forensic odontology

by providing objective, reproducible, and highly detailed records of dental structures. The integration of advanced imaging techniques, such as CBCT, enhances the precision of forensic analyses, facilitating more accurate human identification, trauma assessment, and age estimation. One of the key advantages of imaging in forensic odontology is its non-invasive nature, which allows for the preservation of evidence while minimizing the risk of damage to remains.³

In mass disaster scenarios, imaging technologies enable rapid identification by allowing forensic odontologists to compare ante-mortem and post-mortem records seamlessly. This capability is critical for disaster victim identification (DVI) processes, where timely and accurate identification is paramount. Additionally, imaging supports the documentation and presentation of forensic evidence in court, enhancing the credibility and reliability of expert testimony.²

Despite its numerous advantages, the application of imaging in forensic odontology also presents challenges. Factors such as image quality, operator expertise, and the availability of ante-mortem records can influence the accuracy of forensic analyses. Moreover, the high cost of advanced imaging equipment may limit access in some forensic settings, highlighting the need for continued research and investment in affordable imaging solutions.⁴

Overall imaging technologies, particularly CBCT, have revolutionized the field of forensic odontology by providing unprecedented levels of detail and accuracy. As technology continues to evolve, the integration of imaging in forensic practice is expected to expand, further enhancing the field's ability to contribute to the pursuit of justice.

Conclusion

CBCT has revolutionized imaging modality in forensic odontology by enhancing the accuracy and depth of forensic investigations. Its ability to provide non-invasive, high-resolution, three-dimensional imaging plays a vital role in human identification, trauma analysis, and age estimation. As technological advancements continue to shape the field, CBCT's applications are expected to expand, further strengthening forensic odontology's contribution to the justice system. Continued investment in research, training, and equipment accessibility will be crucial to overcoming existing challenges and maximizing the potential of CBCT in forensic practice.



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