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# Cone Beam Computed Tomography (CBCT) In Forensic Odontology: A Newer Approach

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## Abstract

CBCT provides a superior three-dimensional image production compared to CT. CT uses a fan shaped beam to produce series of axial images which are reconstructed to 3D image. CBCT has a cone shaped beam with high resolution 2D image receptor to produce high resolution images with isotropic voxels in all planes at less cost and radiation dose to CT. CBCT has led to a paradigm shift in dental imaging technology by giving effective knowledge. CBCT has advantages of being a low cost, low dose, space saving alternative with high resolution images in all planes with rapid scan time and less artifacts compared to CT scan. CBCT has countless applications because of its three-dimensional imaging in dental field and holds a promise in the field of forensic odontology as well with its radiographic accuracy. This review aims to provide wider review of available literature up-till now of CBCT applications in the field of forensic dental sciences.

**Keywords:** CBCT; CT; Forensic odontology

## Introduction

Forensic odontology is "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." Forensics refers to cases that can be used in a judicial setting which are accepted by the law and helps to separate truth from untruth [1]. Identification based on teeth has significantly contributed to identification of dead individuals from history to present, the first case being accepted by the law in the year 1849 [2]. Forensics deals with the identification of the dead using numerous techniques. Multiple methods like uroscopy, bite marks, palatal rugae, photographs, lip prints, etc. are used for identifying the individuals but they depend on soft tissue and it is difficult to get intact soft tissues for identification in forensic scenario. In the human remains, teeth, facial bones are the hardest structures, which are unaffected by the decompositional/ destruction forces and under extreme forces or any temperature variations. Teeth radiography is simple and easy method and becomes an invaluable tool in forensic sciences. Radiographic identification of teeth and jaws is efficient, easy, simple and records can be obtained in both living and dead person. It has more preference to DNA analysis as it is less expensive. Radiographic identification with specialized radiologic examinations provides and accurate efficient matching of unique features on ante and postmortem radiographs. It also overcomes the radiographic errors, time consuming practices, less accurate images encountered in conventional techniques.

Personal identification, age and gender determination are of paramount importance to the individual and society in case of mass disasters. It is generally seen in the field of forensic odontology that optimum estimates of age and sex can only be achieved through a multifactorial approach; by applying two techniques of assessment to a specific case. There is dental development variation in the individuals of same population and different ethnicity and groups. Thus, calibration of dental age and gender assessment should be done concerned to local population is most accurate to get the desired accurate results.

As such, the following requirements are mandated for the purpose of radiographic assessment for age and sex estimation in forensic context

1. Obtaining appropriate radiographs and specimens from the subject,
2. The obtained material should be like the one used in the selected age prediction method so that direct and valid comparisons can be conducted,

Selection of the appropriate age prediction method is based on one's understanding of the method and its suitability to the subject, besides understanding and compliance with the legal requirements (Ciapparelli; Panchbhai) [3,4]. CBCT can allow the dental examination of dead bodies when mouth opening is impossible and for yields information for screening by investigating unidentified bodies. CBCT has following applications in forensic that is premortem forensic and postmortem forensic premortem forensics include age and sex determination using CBCT and postmortem forensics include frontal sinus use for personal identification, craniofacial reconstruction [5].

### CBCT in craniofacial reconstruction

Concept of facial reconstruction belongs to anthropology and proves to be quite useful in field of forensics. Facial reconstruction is attempted to reconstruct the face of dead person by studying the Facial contours on skeleton. CBCT is a reliable method to digitize the method of facial reconstruction. CBNCT has a capability to provide very fine details in all three planes which are very accurate can be applied for facial reconstruction.

Sforza *et al.* reviewed various imaging technologies to study three dimensional facial morphology useful in facial reconstruction reported there was a decrease in the error rate in various studies on facial reconstruction after the use of CBCT from 2000 to 2006 [6]. A study by Short L J *et al.* found that faces could be reproduced with error less than ± 2.5mm which ranged from 56% to 90% when CBCT was used for facial reconstruction [7]. Lee W J *et al.* observed CBCT in Korean subjects for facial reconstruction found it to have less than 2.5 mm of error when compared to the relevant target face [8]. Hwang *et al.* constructed a database on CBCT for facial soft-tissue thickness using soft-tissue landmarks as described by De Greef *et al.* [9,10].

### Advantages of CBCT for facial reconstruction

1. Noninvasive procedure producing 3Dimages.
2. Ability to restrict size of exposed area by using different FOV thereby reducing overall radiation dose.
3. Lack of superimposition.
4. Absence of geometric distortion. Measurements made on the images are accurate.
5. Software to analyze images are user friendly and have multiple tools that help to modify scanned images
6. It provides multi-planar reconstruction mode for images. Images can be visualized in different windows, that is, axial, coronal, sagittal, and 3D-reconstructedimages.
7. Different rendering tools are available. These are (1) maximum intensity projection, (2) surface rendering, (3) soft-tissue density, and (4) different colour schemes.
8. Imaging of dentomaxillofacial region can be performed accurately avoiding image artifacts arising from metallic dental restorations and appliances. “Virtopsy” along with fluoroscopic system in CBCT was introduced by Pohlenz *et* al. and had the advantage of obtaining isocentric fluoroscopic images that can overcome the errors of artifacts due to metallic restorations on CBCT images and could also provide better visualisation of soft tissues.

## Limitations

The soft tissues are not as accurately visible in CBCT images as in MRI and ultrasonography (USG).

The resolution of CBCT images is not as high as that of CT scan the energy of X- rays use in CT scan is of high intensity compared with CBCT.

## Frontal Sinus and CBCT

The frontal sinuses can provide significant evidence for forensic identification. The frontal sinus characteristics and its applicability for criminal investigations have been studied for many years, is very useful in edentulous individuals. Frontal sinus pattern is unique for every individual and radiographic assessment aids in personal identification in forensic applications by using Yoshino classification of frontal sinus [12].

CBCT can provide as a useful replacement for study of pattern of Frontal sinus with its accuracy. Some anatomic references for axial and sagittal plane should be identified so that all sinus boundaries are seen with minimal error margin for morphometric comparison of ante and postmortem scans. Beani *et al.* reported a good success in identification of persons by making 3D models from CBCT scans. Frontal sinus pattern matching is superior to two-dimensional imaging and thus provides accurate results [13,14]

## Bitemark Analysis and CBCT

CBCT assisted bitemark analysis is nondestructive, accurate and efficient. CBCT data will have no distortion and 3 D measurement and orientation is possible. Bitemark analysis can be done even if foodstuff is left under room temperature for hours [15]. Marques J*et al.* found CBCT scans were successful

in determining depth of bite mark in all foodstuffs except pizza. Cone Beam Computed Tomography has the potential to become an important tool for forensic sciences, namely for the registration and analysis of bite marks in foodstuffs that may be found in a crime scene [16].

## CBCT in Sex and Age Determination

Sexual dimorphism is an important aspect in personal identification which helps to narrow down the identification process. Skull has 95% of accuracy rate for sex determination. Skull bones are relatively indestructible and denser which are often recovered intact at crime scene can be applied for sex determination. Studies reporting anthropometric measurements of structures for sex determination using CBCT are for following structures 1. Mandibular measurements 2. Foramen magnum 3. maxillary sinus 4. Frontal sinus 5. mastoid process.

Yang *et al.* correlated the chronological age of an individual and the pulp/tooth volume ratio of teeth by a custom-made voxel counting software for calculating the ratio pulp tooth ratio for age determination [17]. Jagannathan et al. calculated pulp tooth ratio from CBCT scans of 140 individuals for mandibular canine in Indian population and proposed it to be a useful technique for age estimation [18]. Star *et al.*evaluated pulp tooth ratio from CBCT scans of all teeth and found that incisors more accurate in age determination [19]. Alam *et al.* evaluated the tooth size and arch dimension by CBCT scans and found that canines showed maximum sexual dimorphism [20]. Gamba *et al. s*tudied CBCT images and measured mandibular images by measuring ramus length, gonion- gnathion length, minimum ramus breadth, gonial angle, bicondylar breadth, and bigonial breadth for the sexual dimorphism analysis which was 95% accurate in gender determination [21]. Ilguy*et al.* reported foramen magnum and mandibular measurements such as gonial angle and ramus, gonion- gnathion lengths, and bigonial breadth of the mandible evaluated preexisting CBCT scans to be used for gender determination in unknown skull remains [22]. Foramen magnum can be used for sexing when other methods are not applicable was advised by Jaitley M*et al*., Akay et al also suggested that its sagittal, transverse and circumference show sexual dimorphism [23,24]. Urooge *et al.* reported in their study that maxillary sinus CBCT scans can be used as an aid in forensics for gender determination with overall accuracy of 71% [25]. Gamba *et al.* emphasised combined use of mandibular canal and maxillary sinus for sex determination with two together with 78.5% accuracy in Dutch population [26]. Pakanahad M *et al.* supported that height measurement in maxillary sinus is predictable factor for sex determination from CBCT scans [27]. Gomes A *et al.* found that CBCT measurements of maxillary sinus had 94% precision in Brazilian population for sex determination [28]. Although above studies reported that CBCT scan software would accurately and easily measure maxillary sinus dimensions Saccuci*et al.* reported in their study that maxillary sinus should not be used for gender determination [29]. Amin et al reported that mastoid process radiographic study with CBCT correctly identified gender in 90.6 % cases using discriminant function analysis and inter mastoidal distance was best determinant for sex in Jornadian population [30]. CBCT and age estimation studies Pinchi V*et al.* reported CBCT provides easy accurate tooth volume calculation [31]. Rhee *et al.* used second vertebrae as predictable marker on CBCT for prediction of bone and forensic age showed good accuracy. CBCT is the choice to evaluate sphenooccipital synchondrosis for age estimation around the age of 18 years reported by Sinanoglu *et al.* CBCT in various age estimation studies proves to provide a solution which is more accurate, easy to manipulate and multiple functions can be applied through programs and faster [32].

## Conclusion

CBCT in forensic radiology holds a strong promise through its applications which are major so possibility of deceased CBCT scans obtaining are high and its accurate with its high radiographic image quality. CBCT scans of deceased will have high applications in digital facial reconstruction and bite mark analysis with wide scope of CBCT software with its simplicity and fast retrieval of results with high accuracy. CBCT provides a more precise and standardized imaging modality to conventional radiography for age and gender determination with its high precision. CBCT is a new age modality and multiple studies which are population specific should be conducted to provide an evidence scientifically for application of CBCT in forensic odontology.

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