e - ISSN - 2349 - 8005

INTERNATIONAL JOURNAL OF ADVANCES IN CASE REPORTS

Journal homepage: www.mcmed.us/journal/ijacr

THE ROLE OF CBCT IN FORENSIC DENTISTRY: A REVIEW

Moazzam Jawaid*, Md Asad Iqubal, Anjani Kumar Shukla, Mobeen Khan, Bushra Farhat.

Post Graduate Students, Department of Oral Medicine and Maxillofacial Radiology, Institute of Dental Sciences Bareilly, India.

Corresponding Author:- **Moazzam Jawaid**
E-mail: moazzamjawaidmds@gmail.com

Article Info

Received 15/12/2014
Revised 27/12/2014
Accepted 12/01/2015

Key words: CBCT, forensic dentistry, age estimation, sex-determination.

ABSTRACT

Cone Beam Computed Tomography (CBCT) is a new application of Computed Tomography (CT) that generates three-dimensional (3D) data at lower cost and less radiation than conventional CT found in the practice of medical radiology. Data from the craniofacial region are often collected at higher resolution in the axial plane than those from conventional CT systems. These systems do not require a large amount of space and can easily fit into most dental practices. Most of the attention regarding CBCT imaging has focused on applications for dental implant placement, orthodontics, oral and maxillofacial surgery and temporomandibular joint imaging and not as much emphasis has been placed on the applications of CBCT in the forensic dentistry. This article reviews and examines the available evidence from the clinical and scientific literature pertaining to forensic dentistry primarily limited to two basic areas: pre-mortem forensic including age estimation and sex determination, and post-mortem forensic including facial reconstruction and frontal sinus examination for the forensic identification.

INTRODUCTION

Cone-beam computed tomography (CBCT) is a relatively new imaging modality. The introduction of dentomaxillofacial CBCT scanners in the late 1990s has led to an explosion of interest in these devices in the field of dentistry. It has the obvious advantage of relatively low-cost and low-dose. CBCT differs from CT in that it uses a single X-ray source that produces a cone beam of radiation (rather than a fan beam, as with CT). CBCT uses a single, relatively inexpensive, flat-panel or image intensifier radiation detector. CBCT imaging is performed using a rotating platform to which the X-ray source and detector are fixed. As the X-ray source and detector rotate around the object, it produces multiple, sequential, and multiplaner images that are mathematically reconstructed into a volumetric dataset. A single rotational sequence would capture enough data for volumetric image construction. The radiation exposure is low because the target region is scanned in a single rotation [1]. CBCT may be very useful in some forensic procedures, offering several advantages for pre-mortem forensic and post-mortem forensic imaging including good resolution for skeletal imaging, relatively low cost, portability, and simplicity [2]. It provides a noninvasive alternative for age estimation which is an important aspect of forensic dentistry [3]. The pulpo-dentinal complex (dentin, cementum, and the dental pulp) shows physiologic and pathological changes with advancing age [4]. Generally, extraction and sectioning are required to quantify these morphological changes, which is not always a viable option.

The radiographs of cranium, face, long bones and tooth have been mostly used for forensic identification. Among them, face radiographs are better considered particularly because of the presence of diverse geometrical contours which allow a precise superimposition into an identity. With the advent of cone beam computed tomography, which shows higher precision to diagnose traumas of cranium - the number of image requests by forensic professionals has increased, making possible the use of this technique to support human identification by comparing images of significant anatomical structures of the cranium [5].

Pre-Mortem Forensic

CBCT plays important role in forensic purpose like age estimation and sex determination in living individuals.

Age Estimation

The identification of age in anthropology and forensic medicine is sometimes difficult, but nonetheless important. Several methods based on the analysis of teeth have been reported in the literature to estimate the unknown age of individuals. The most widely used methods include the analysis by Gustafson [6] andJohanson's [7] method, as well as the assessment of dentinal translucency [8] and of cementum annulations [9,10]. Some methods are destructive and are therefore not appropriate for living individuals. Examination of the pulp space offers new opportunities in dental age identification. A commonly used method found to be effective is the evaluation of secondary dentine apposition [11]. This apposition is a continuous, age-associated process, which alters the size of the pulp chamber and is only modified under pathological conditions like caries. Various methods have been developed to study the size of the pulp chamber, including tooth cross-sections and radiographs. Both panoramic and periapical radiographs have been used to assess the pulp/tooth area ratio of maxillary canines [12]. The primary disadvantage of radiographs is that they are two-dimensional projections which are subject to considerable magnification and distortional errors. Therefore, a simultaneous assessment of the mesio-distal and bucco-lingual dimensions of teeth has been recommended. Cone beam Computed tomography (CBCT) is the ideal and most accurate method for this purpose [13].

A study conducted by N. Jagannathan et al in 2011 assessed the suitability of pulp/tooth volume ratio of mandibular canines for age prediction in an Indian population using CBCT. Volumetric reconstruction of scanned images of mandibular canines from 140 individuals (aged 10 - 70 years), using CBCT was used to measure pulp and tooth volumes. Age calculated using a formula reported earlier for a Belgian sample, resulted in errors > ten years in almost 86% of the study population [14]. Besides, the visualization of cervical vertebral morphology holds potential in skeletal age assessment. Shi et al, in their study, concluded that segmentation of individual vertebrae was possible using CBCT volumetric datasets. This provides a 3D approach to the biologic aging of orthodontic patients by using images of the cervical spine. It also holds potential in studying disease processes such as spinal fractures consequent to osteoporosis [15].

Sex Determination

Sexual dimorphism can be evaluated by using anthropometric measurements on mandibular images obtained by cone beam computed tomography (CBCT). Preferably, six measurements (ramus length, gonion−gnathion length, minimum ramus breadth, gonial angle, bicondylar breadth, and bigonial breadth) are used for the sexual dimorphism analysis. It is evident that from the six mandibular measurements three of them show significantly higher mean values in males than in females. These are: bicondylar breadth, gonial angle and minimum ramus breadth [16].

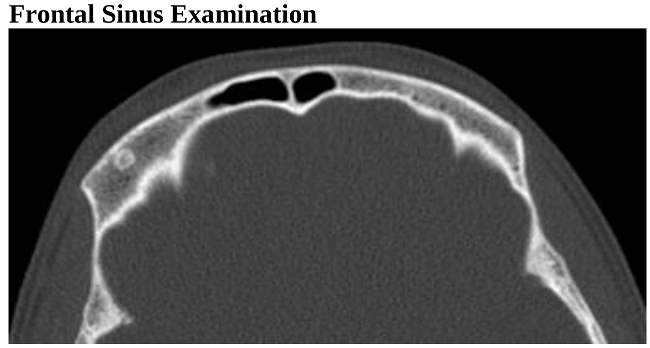
A study was done among white South Africans to establish which mandibular measurements give most information about the differences between males and females. Bigonial breadth was selected as the most discriminatory and obtained average accuracies of82% for mandible [17].

T. De Oliveira, Gamba M, Corrêa Alves F. Haiter-Neto conducted a study using anthropometric measurements on mandibular images obtained by cone beam computed tomography (CBCT). The sample consisted of 159 CT scans collected from a Brazilian population (74 males, 85 females) aged 18–60 years. The CBCT images were analyzed by five reviewers. Six measurements (ramus length, gonion−gnathion length, minimum ramus breadth, gonial angle, bicondylar breadth, and bigonial breadth) were .collected for the sexual dimorphism analysis. Using these four variables, the rate of correct sex classification was 95.1% [18].

Post –Mortem Forensic

CBCT can be used for forensic identification in dead bodies by frontal sinus examination and facial reconstruction.

Frontal Sinus Examination



Axial CT image showing frontal sinus

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, particularly in edentulous individuals. Its use in successful identifications has been widely accepted by anthropologists, radiologists, pathologists and the court of justice as judicial evidence with scientific validity. The irregular forms of the frontal sinuses, initially observed in anterior-posterior radiographs have been extensively studied since the first assumption that these are found to show an individual pattern like fingerprints. It has been proven that there are not two people with the same frontal sinuses, even being monozygotic twins. The comparison of frontal sinus images by cone-beam computed tomography can be used as an additional method in the identification process, providing the expert with a greater reliability [5].

To describe the use of CBCT as an alternative to obtaining images of the frontal sinuses it is proposed the adoption of some anatomic references to do the axial slicing, which should have its plan being tangent to the upper limit of the orbital cavities, as well as the sagittal slicing, which should be done under the midline, so that all sinus boundaries would be observed while error margin in obtaining comparative images would be reduced. The identification results from the morphometric comparison of the frontal sinuses ante- and post-mortem, with regard to forms, size and contours in the images available [5].

Human identification is not a difficult task, when it is about a live individual or a cadaver chronologically recent and intact. However, when there is not a complete skeleton, but a group of bones, the identification process becomes progressively harder and sometimes impossible to be accomplished. This technique can be applied for forensic identification of an intact cadaver as well as of a group of bones especially the cranium bones [5].

Facial Reconstruction (Computerized Facial Reconstruction)

Estimation of facial soft tissue appearance from human skeletal remains is often necessary in forensic identification. This process has been referred to as facial reconstruction or facial approximation and is a branch of forensic facial anthropology. Original methods for facial approximation originated in nineteenth century in Europe and consisted of artists shaping clay over skull models using average soft tissue depths measured in cadavers. The last two decades have introduced numerous computerized techniques using CBCT that have digitized this process while attempting to accurately and objectively define the relationship between a skull and its overlying soft tissue.[19]

The human skull contains enough unique complexity to be as distinct as a fingerprint [20]. Claes et al. 2010 have contributed an exhaustive overview that unifies contemporary efforts in the field of computerized facial reconstruction into one frame work. This frame work consists of the following elements: anthropologic examination, skull digitization, craniofacial model, target skull representation, model to skull registration, visualization, and validation [21]. CBCT plays important role in this procedure by helping in unknown skull digitization and craniofacial model formation [22].

Unknown Skull Digitization

Initial methods for importing a digitized version of the unknown skull in computer systems consisted of laser scanning technology [23]. Advances in medical imaging have made computer-tomography (CT) a convenient method of deriving digital skull models. All computerized reconstruction techniques today use CT scanners to digitize the skull [21]. Cone-beam computed tomography (CBCT) is a variant of medical CT that is commonly used in dentistry that can produce similar resolution in digitization of the skull while producing lower levels of radiation [24]. CBCT imaging is now also being used in contemporary facial reconstruction studies. Each imaging technique has its limitations. CT and CBCT introduce significant artifacts as a result of dental amalgam fillings, and laser scanning processes result in resolution and detail deficiencies [21] Compared to CT, CBCT has the benefit of image production with the subject in seated position. CT scanners operate with the patient in supine position, and this can introduce gravitation deformation of soft tissues [25].

Craniofacial Model

According to Claes et al. (2010), an essential step in the computerized facial reconstruction framework is the definition of a craniofacial model (CFM). Conceptually, this step is the incorporation of artificial intelligence that is functionally analogous to the human artist that creates manual facial reconstructions. The craniofacial model is responsible for establishing the relationship between skull structures and facial form based on a database of example relationships. An example relationship exists in each living person, because in a live person a skull is matched with an actual face that we can observe [21]. This relationship is conserved properly during skull digitization due to the anatomical accuracy being present in CT or CBCT imaging.[26]In this way CBCT plays important role in human identification by facial reconstruction technique.

Advantages

1. CBCT is a non invasive technique in forensic dentistry as compared with other techniques used in forensic dentistry [3].
2. Most CBCT machines allow operator to select the desired region of interest (FOV). One can thus image a volume of only three teeth when localized information is required and also larger regions like maxilla and mandible or entire craniofacial complex [27].
3. Practical advantages include relatively small size, portability, and low cost. Technical advantages include good spatial resolution and metal artifact reduction [2].
4. CBCT images can be acquired in few seconds especially if the volume to be imaged is smaller. Scan time is comparable to panoramic radiograph [28].
5. Images are seen in multiplanar format and the operator can scroll through the entire depth of tissue in multiple slices as described. Three-dimensional reconstruction can be obtained with display from any angle [1].
6. Images are dimensionally accurate. With CBCT, the projectional magnification is computationally corrected during primary reconstruction, creating an orthogonal image with 1:1 ratio [29].

Disadvantages

1. CBCT is more expensive than conventional radiologic investigations [30].

2. CBCT images suffer from increased noise from radiation scattered in many directions. Compared with CBCT, CT images have less noise, which is due to superior collimation of the exit beam in CT machines but it results in greater patient exposure [28].
3. Streaking and beam hardening artifact have been noted when radiation passes through dense objects (amalgam restorations and implants) and does not reach the receptor [31].
4. CBCT suffers from motion artifact when a patient moves during the scanning process . It can be avoided by using head stabilizing devices but any movement affects the whole data set and the whole image rather than just one part [32].
5. Limitations include limited field size and limited soft tissue contrast [2].

CONCLUSION

Often, dental professionals and forensic doctors are called to provide clarification to the court of justice for forensic identification. As crimes have become increasingly sophisticated, new forensic investigation techniques need to be improved and developed following the emergence of new technological resources. CBCT imaging can provide the much-needed 3-D perspective in certain cases that require more information than can be obtained from traditional methods. The use of this technology is yet limited and there is a need for dental professionals or forensic doctors to understand the role of this imaging modality. CBCT in future will prove to be a great tool for forensic dentistry.

REFERENCES

1. Dessai SR, Barretto E, and Swamy D. (2014). Cone Beam Computed Tomography, A Comprehensive Review. Research and reviews. *Journal of Medical and Health sciences*, 3(2), 1-10.
2. Sarment DP, Christensen AM. (2014). The use of cone beam computed tomography in forensic radiology. *Journal of Forensic Radiology and Imaging*, 2(4), 173–181.
3. Yang F, Jacobs R, Willems G. (2006). Dental age estimation through volume matching of teeth imaged by cone-beam CT. *Forensic Sci Int*, 159(1), 78–83.
4. Erickson M, Caruso JM, Leggitt L. (2003). Newtom QR-DVT 9000 imaging used to confirm a clinical diagnosis of iatrogenic mandibular nerve paresthesia. *J Calif Dent Assoc*, 31(11), 843–845.
5. Marques J A M, Musse J O,Gois B C, Galvão L C C,Paranhos L R. (2014). Cone-beam computed tomography analysis of the frontal sinus in forensic investigation. *Int J Morphol*, 32(2), 660-665.
6. Gustafson. (1950). Age determination on teeth. *J Am Dent Assoc*, 41, 45-54.
7. Johanson G. (1971). Age determination from teeth. *Odontol Revy*, 22, 1-126.
8. Bang G, Ramm. (1970). Determination of age in humans from root dentine transparency.Acta Odontol Scand.8, 3-35.
9. Kagerer P, Grupe G. (2001). Age-at-death diagnosis and determination of life-history parametersby incremental lines in human dental cementum as an identification aid. *Forensic Sci Int*, 118, 75-82.
10. Wittwer-Backofen U, Gampe J, Vaupel JW. (2004). Tooth cementum annulation for age estimation, Results from a large known-age validation study. *Am J Phys Anthropol*, 123, 119-129.
11. Paewinsky E, Pfeiffer H, Brinkmann B. (2005). Quantification of secondary dentine formation from orthopantomograms acontribution to forensic age estimation methods in adults. *Int J Legal Med*, 119, 27-30.
12. Cameriere R, Ferrante L, Belcastro MG, Bonfiglioli B, Rastelli E, Cingolani M. (2007). Age estimation by pulp / tooth ratio in canines by periapical X-rays. *J Forensic Sci*, 52, 166-70.
13. Yang F, Jacobs R, Willems G. (2006). Dental age estimation through volume matching of teethimaged by cone-beam CT. *Forensic Sci Int*, 159(1), 78-83.
14. N. Jagannathan et al. (2011). Age Estimation In An Indian Population Using Pulp/Tooth Volume Ratio Of Mandibular Canines Obtained From Cone Beam Computed Tomography. *J Forensic Odontostomatol*, 29, 1, 1-6.
15. Shi H, Scarfe WC, Farman AG. (2007). Three-dimensional reconstruction of individual cervical vertebrae from cone-beam computed-tomography images. *Am J Orthod Dentofacial Orthop*, 131(3), 426–432.
16. Kharoshah M A A et al. (2010). Sexual dimorphism of the mandible in a modern Egyptian population. *Journal of Forensic and Legal Medicine*, 17, 213–215.
17. Steyn M, Iscan MY. (1998). Sexual dimorphism in the crania and mandibles of South African Whites. Forensic Sci Int. 98, 9–16.
18. Gamba T D O,M. Corrêa Alves M C,Neto F H. (2014). Mandibular sexual dimorphism analysis in CBCT scans of a Brazilian population. *Journal of Forensic Radiology and Imaging*, 2(2), 104.
19. Nejat, Behzad. (2012). A Forensic Identification Utility to Create Facial Approximations using Cone-Beam Computed Tomography of 100 Hispanic Females, A Pilot Study UNLV Theses/Dissertations/Professional Papers/Capstones. 1763, 25-60.
20. Schimmler J B, Helmer R P, Rieger J. (1993). Craniometric individuality of human skulls. Forensic Analysis of the Skull Wiley-Liss, Inc New York. 89-96.

21. Claes P, Vandermeulen D, De Greef et al. (2004). Computerized craniofacial reconstruction, Conceptual framework and review. *Forensic Science International*, 201 (1), 138-145.
22. Lee W J, Wilkinson C M, Hwang H S. (2012). An Accuracy Assessment ofForensic Computerized Facial Reconstruction Employing Cone- Beam Computed Tomography from Live Subjects. *Journal of Forensic Sciences*, 57(2), 318-27.
23. 23.Moss J P, Linney A D, Grindrod S R., Mosse C A. (1989). A laser scanning system for the measurement of facial surface morphology. *Optics and Lasers in Engineering*, 10(3), 179-190.
24. Mah J K, Yi L, Huang R C, Choo H. (2011). Advanced applications of cone beam computed tomography in orthodontics. In Seminars in Orthodontics, 17(1), 57-71.
25. Pluym J V, Shan W W, Taher Z, Beaulieu et al. (2007). Use of magnetic resonance imaging to measure facial soft tissue depth. *The Cleft palate-craniofacial Journal*, 44(1), 52-57.
26. Suomalainen, A., Vehmas, T., Kortesniemi, M., Robinson, S., & Peltola, J. (2008).Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography. *Dentomaxillofacial Radiology*, 37(1), 10-17.
27. Levato CM, Farman AG, Chenin DL. (2009). Cone Beam Tomography, A Clinicians Perspective. Inside Dentistry. 2 - 6.
28. Scarfe WC, Farman AG. (2007). Cone Beam Computed Tomography, A Paradigm Shift for Clinical Dentistry. Australasian Dental Practice, 102 -117.
29. Pinsky HM , Dyda S , Pinsky RW, Misch KA, Sarment DP. (2006). Accuracy of three-dimensional measurements using cone-beam CT. *Dentomaxillofacial Radiol*, 35, 410- 416.
30. Tetradis S, Anstey P, Radford SG. (2010). Cone Beam Computed Tomography in the Diagnosis of Dental Disease. CDA J. 38, 27-32.
31. Draenert G, Coppenrath , Herzog P, Muller S, Mueller-Lisse UG. (2007). Beam hardening artefacts occur in dental implant scans with the NewTom cone beam CT but not with the dental 4-row multidetector CT. *Dentomaxillofacial Radiol*, 36, 198 – 203.
32. Neto R, Mudrak J, Matzen LH, Christensen J, Gotfredsen E , Wenzel A. (2013). Cone beam CT image artefacts related to head motion simulated by a robot skull, visual characteristics and impact on image quality. *Dentomaxillofacial Radiol*, 42(2), 32310645.