TPM Vol. 32, No. S5, 2025
ISSN: 1972-6325
https://www.tpmap.org/

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APPLICATION OF CBCT IN FORENSIC ODONTOLOGY

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Abstract
In the recent decades, Conebeam computed tomography (CBCT) has made a revolutionary change in the diagnosis and treatment planning in dentistry. This marvelous imaging technology has been utilized now in the field of forensic odontology replacing the conventional two dimensional imaging modalities. Cbct plays a pivotal role in personal identification; age estimation, sex determination, comparative analysis, etc. The present review aims to provide a in depth understanding of the role of CBCT in forensic odontology.

INTRODUCTION

Mankind has witnessed an enormous development in science and technology, especially in the last era. This meticulous development, especially introduction of digital technologies has gained it's establishment in all fields of medicine and dentistry. In fact, Cone Beam Computed Tomography (CBCT) has added a new dimension in the diagnostic approach in the field of dentistry. [1] This volumetric imaging modality has gained it's stance in almost all branches of dentistry as it is precise, offers high quality of anatomical data and promises less distortion of the image with low doses of radiation.[2] As an CBCT is a cost effective three dimensional imaging method, it's horizon has been widened recently and has been used in forensic odontology. [3] Hence, the present review aims to elaborate on the application of CBCT in forensic odontology.

Overview of Cone Beam computed tomography (CBCT):
In 1972, G.N. Hounsfield introduced computerized transverse axial scanning (CAT) or CT scanning, which overcame the limitations of the 2D radiographic imaging (superimpositions, distortions etc.). [4] However, this modalities implication in dentistry was held back because of the high cost, availability, longer scanning time, and high radiation exposure.[5] A novel modality called Cone Beam computed tomography (CBCT) which was initially built for angiography, have now become an important mode of 3D imaging by overcoming the limitations of CBCT especially in dentistry. [6]
CBCT uses a cone shaped X ray beam rather than a fan shaped beam as in CT, hence, has a rapid scan time which is comparable to panoramic radiography (5-40 seconds). A single rotation is sufficient to acquire basis images for 3D imaging. This short scanning time is advantageous in plummeting the artifacts owing to patient movement. [7]
Most imprtantly, the recent implication of artifact suppression algorithms in CBCT has led to low levels of metal artifacts, mainly in secondary reconstructions intended for seeing the jaws and teeth. [8] In dentistry, CBCT is used in diagnosis and treatment planning. Apart from these, CBCT are used in forensic dentistry for the purpose of personal identification.
Forensic odontology:
Forensic dentistry plays a major role in the identification of those individuals who cannot be identified visually or by other means. [10] Human identification is of paramount importance and it is indeed challenging considering the fact that every individual has distinctive traits. Teeth are one of the strongest structures in the body, and are usually resistant to postmortem decomposition. Also, Bones of calvarium are resilient to destruction or decomposition. Moreover, most materials used by the dentist for restoring and replacing teeth are also resistant to postmortem changes. Therefore, from a forensic point of view, application of teeth, bones of the calvarium are important in establishing the identity of badly burned, traumatized, decomposed, and skeletonized remains. [11]
In forensic odontology, radiographs play a Pivotal role, especially in personal identification. [12] The application of radiology in forensic sciences was introduced in just one year after the discovery of X ray by Roentgen, to

demonstrate the presence of lead bullets inside the head of a victim. [13] Following which, radiographs were used in almost all fields of forensics such as age estimation, sex determination, comparative dental identification, post mortem dental profiling, etc. [14]

CBCT in forensic odontology

With the technical development and ease of availability of CBCT to the general population, this modality has also replaced the application of conventional radiography in forensic odontology.

A. Age estimation

In assessment of the chronological age of an individual either living or dead, CBCT can be utilized. Historically age assessment using teeth was first published by Edwin Saunders in 1837, who claimed that teeth provided the most reliable guide to age compared to age estimation from height which was a standard method used during that time.[15] Radiography can provide the gross stage of dental development of the dentition. Age estimation using the dentition can be grouped into three phases, Phase I- Prenatal, neonatal and postnatal, Phase II - Children and adolescents and Phase III -Adults.

In Prenatal, Neonatal And postnatal age estimation, the radiographic examination can reveal the crypt, and as the mineralization of tooth germs starts, the tooth germs may be visible as radiolucent areas on the radiograph.During assessment of age in children and adolescents, tooth eruption and tooth calcification are the two events that can be used to measure dental age in children and adolescents. [16]

However, for estimating the age in adults, two methods are commonly followed; assessment of volume of teeth and the development of the third molar. With aging, there is reduction in size of the pulp cavity arising from a secondary dentine deposition. Several studies have indicated a strong inverse relationship between pulp volume and age. [17-21] Multirooted teeth are usually not studied for age estimation because the pulp changes are less evident in the root, although they are clear in the canal. [28] However, a recent meta-analysis had reported that the strongest and weakest relationships were observed in the mandibular first molars and mandibular third molars, respectively. [22] Apart from first molars and canines, central incisors and premolars are also used for assessment of pulpal volume of teeth.[27] Patel et al [25] and Sukhadeve et al [26] reported that pulp width of maxillary central incisor, and premolars are a reliable indicator of age estimation while utilizing CBCT images. Kazmi et al [29] found a statistically significant difference in volumes of pulp between males and females and that mandibular canine pulp volume and sex had the highest predictive power in estimating the age of deceased persons. Hatice Çelik et al devised a regression formula for age estimation specific to the Anatolian population using the Kvaal method on CBCT reconstructed panoramic images of 201 individuals aged between 20 and 69. The authors concluded that the regression formulae derived was found to be statistically applicable and reasonably accurate and maxillary teeth provided more accurate age estimates than mandibular teeth. [30]

Development of the third molar can be a maturity marker in adolescents to adults. However, after a complete eruption, this marker is not often of much value. Yurdabakan et al performed a study on 122 CBCT scans of Turkish individuals (55 boys and 67 girls) aged 13 to 23 years to evaluate the I3M cutoff value. The authors reported that overall accuracy, sensitivity and specificity of the third molar maturity index (I3M) were 95.9%, 93.5% and 97.4%, respectively. [23] Kunuk et al reported that from the CBCT images, the age of individuals and whether they are below or above 18 years can be estimated by evaluating the development of third molars according to the Demirjian method.[24]

Application of CBCT is advantageous than conventional radiography, as CBCT provides a three dimensional view of the pulp chamber i.e., buccolingual measurements for calculating the pulp tooth ratio, by providing dimensionally accurate images with easy tools for measurements and calculation.

Another method that has recently been taken into consideration for age estimation is the analysis of spheno occipital synchondrosis. Spheno-occipital synchondrosis is a pivotal growth center that is involved in craniofacial development, particularly in the dentofacial region. Since osteogenesis of spheno-occipital synchondrosis occurs relatively later than other cranial base synchondroses that go through osteogenesis before birth or in early childhood, it can be used as a marker for age estimation. [31,32]

Studies have reported a positive correlation between spheno-occipital synchondrosis fusion degree and age. Sheikhi et al analyzed the correlation of spheno occipital synchondrosis fusion degree using a four-stage system and age. They concluded that asses of spheno-occipital synchondrosis fusion alone was not a robust method in age estimation; however, when combined with the third molar development (Demirjian index), it could be considered as an appropriate marker for age estimation in Iranian population. [31,32] In contrast, Mandibular condylar cortication and spheno-occipital synchondrosis fusion were positively correlated with chronological age in Indian population Sridhar Murali et al study. [33]

Sharma et al [34] revealed a linear relationship between the closure of spheno-occipital synchondrosis and age while observing that males tend to attain each stage later than females, and this sexual dimorphism exists till the age of 16 years; thereafter, 100% population shows complete closure of spheno-occipital synchondrosis. Various studies have reported wide variability in the age of closure of spheno-occipital synchondrosis. Also considering the influenced by many factors such as nutritional status, exercise, physical activities, general growth, allometric

growth and development of the bones, spheno-occipital synchondrosis fusion alone is not a reliable method in age estimation; however, when combined with other age assessment tools such as third molar mineralization, cervical vertebrae maturation, etc, it could be considered as an appropriate marker for age estimation. [35,36]

B. Sex determination

Gender dimorphism is apparent in several anatomical features of the skull. Consequently, it is advantageous to be able to detect gender-specific traits of the skull. Measurement of craniofacial parameters plays an important role in sex determination in forensic science. They are frontal sinus, maxillary sinus, foramen magnum diameters, bicondylar width, the condylar height, the coronoid height, the superior border of the mental foramen, mandibular measurements and ramus.

Frontal sinuses are situated between the internal and external laminae of the frontal bone. Frontal sinuses are absent at birth and fully developed around 8 years and reach full size after puberty. [37] Frontal sinuses are important parameters in the determination of sex as it presents a distinctive difference in shape, measurements, and symmetry. Uthman et al in their study of evolution of frontal sinuses and frontal measurements using spiral computed tomography scanning of ninety patients concluded that frontal sinus measurements are valuable aid in differentiating sex and stated that, including skull measurements along with frontal sinus measurements improved the accuracy. Belaldavar et al showed greater mean values of frontal sinus height, width, and area in male compared to females. Takkella et al reported that right frontal sinus height and width, and frontal sinus index were higher in males than in females. Left frontal sinus height, width, and frontal sinus index were higher in males than in females. Left frontal sinus height and width were statistically significant, depicting the sexual dimorphism.[37] Anastasia Mitsea et al in their Systematic literature review search reported that frontal sinus volume (FSV) and frontal sinus height (FSH) are significantly greater in males than in females.

Foramen magnum is a three-dimensional opening in the central region of the base of the occipital bone and is an anatomical landmark that marks the transition zone between the spine and the skull. The foramen magnum and the adjacent area around it are relatively indestructible due to the nature of the hard tissue, with the thickness of the occipital bone and its protective anatomical position making it amenable for use in forensic identification and sex determination. [30]

D. Facial reconstruction

Forensic facial reconstruction is a technique to reconstruct a human face from unidentified facial and skull remains for positive human identification and facial recognition. CBCT produces feasible 3D craniofacial reconstructions, with a minimal radiation exposure. [25] Hwang et al in their study indicate that CBCT images can be used to measure ST thickness with high reproducibility. However, some landmarks need to be redefined to reliably measure ST thickness on CBCT images.[56] Even though, soft tissue measurement with CBCT gives more accurate pictures, some postural errors may raise differences in measurements. A study conducted by Munn and Stephan with 62 patients, demonstrated that postural variation affects the overall average facial soft tissue thickness measurements, especially in the cheeks, eyes and nasolabial fold area. [32]

CONCLUSION

Cone Beam Computed Tomography (CBCT) is a novel imaging technology which has gained it's stance in the field of forensic odontology also. Through CBCT radiology, evolutionary forensic odontology has been developed extensively in many applications, such as the estimation of age through teeth, the role of dentists in trials or forensic witnesses, analysis of bite marks, investigation of trauma cases, and determination of sex and race. The advantages of digital CBCT radiographs include the speed at which radiographs are retrieved, radiograph displays visible directly on a computer screen, and the application of contrast, density, sharpness, image, and color adjustments available on the CBCT digital radiograph software. These help significantly in identification checks in forensic, especially in skeletal and odontology cases.

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