Review Article

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CBCT in Forensic Odontology

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Abstract

This article evaluates various clinical applications of cone-beam computed tomography in fgorensic odontology (CBCT). Cone beam Computed tomography is an alternate imaging modality which can be used to estimate age and to aid on human identification in forensic Dentistry. There are many other application of CBCT for human identification like volumetric changes of teeth, facial measurement, analysis of bite marks on food stuff, by frontal sinus measurement analysis.

Keywords: CBCT; Forensic Odontology; Bite Mark Analysis.

Introduction

Forensic odontology has become an integral part of Forensic Sciences over the past 100 years that utilizes dental or orofacial findings to serve the judicial system. This has been due to the dedication of many researchers that established the essential role that Forensic Dentistry plays an important role mainly in the identification of human remains [1]. The data obtained from the orofacial structure can contribute to estimate age and to determine sex of an unknown individual or provide information needed to justice and security. It needs interdisciplinary knowledge. Furthermore, these data can narrow the search range of an individual and play a key role in the victim identification [2]. Commonly used methods for forensic dental identification are the clinically used radiological documentation techniques such as dental periapical radiographs, bitewing films and panoramic X-ray. In these methods, dental changes related to age like tooth eruption, tooth calcification, attrition, periodontal diseases,secondary dentin deposition, root translucency, cementum apposition, root resorption, color changes and increase in root roughness are analyzed [3,4,5,6]. An alternate imaging modality that is beginning to make ways into medico-legal death investigation around the world is computed tomography (CT) [7 ,8 ,9]. The clinical introduction of cone-beam CT creates new opportunities to get 3-dimensional (3D) tooth radiographs. It has been shown that CT scans cause no magnification errors due to geometric distortion, which are the main drawbacks in conventional radiography [10,11]. Typically, extraction and sectioning of teeth are required to quantify morphological changes, for obtain data like age and sex, but it is not always fruitful. CBCT may provides a noninvasive alternative [12].

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Age Estimation Through Volumetric Changes

Dental age estimation is important in both forensic and clinical work. In the forensic science, age information concern both living and deceased individuals and its estimation applies to both criminal responsibility and marriage law. Teeth are being best to resist destruction, useful in forensic identification of decomposed or skeletonized remains [13]. The pulp-dentinal complex is one of the dental structures that show modifications related to age, mainly resulting in the reduction of the pulp chamber volume due to the continual deposition of secondary dentin.The pulp chamber and root canals are fairly large, in young teeth that have just completed their growth, narrow considerably throughout the life,often

coming to an almost complete obliteration ,by secondary deposition of dentin. The studies to determine amount of secondary dentin in adults are based on destructive methods, which uses sections of teeth and nondestructive methods which uses periapical radiography and panoramic radiography. In 1995 Kvaal et al. described a nondestructive method for age estimation by linear measurement of pulp, tooth and root in six types of radiography of teeth in same dentition and these shows significant influence on age.Cone beam computed tomography (CBCT) created new opportunities for obtaining accurate 3D teeth images with a small dose of radiation and in a noninvasive manner. From initial 3D images it is possible to create multiplanar reformations through easy manipulation software.The CBCT allows a precise and accurate measurement of volume changes of dental hard tissue caused by ageing. The analysis of volume the pulp chamber and tooth is more reliable than calculation of areas, possibly because secondary dentin projected areas could give an incorrect impression of the extent of this process.

3D Reconstruction of Facial Skeletal

Anthropometry provides objective means to assess facial shape and detect shape changes over time. This is important to diagnose acquired malformations, to plan and evaluate surgery, to study normal and abnormal growth, and to differentiate between the results of treatment and normal growth[14]. In addition to linear distances, these techniques potentially allow for the calculations of angles, surface arcs, surface areas, and volumes of the face[15]. Image-processing algorithms applied to facial images have the potential to enhance anthropometric applications through reduction in the time spent on examinations and to improve the reliability of measurements. Automatic extraction of desired facial features or landmarks would enable automatic measurement of clinically relevant information [14]. Cone beam computed tomography (CBCT) systems have been developed specifically for the maxillofacial region [15]. Many devices are capable of large field-of view imaging of the skull, including most anthropometric landmarks used in cephalometric analysis.High dimensional accuracy has been reported for maxillofacial CBCT in measurements of facial structures [17,18,19]. Reduced radiation exposure and submillimeter resolution are just some of the advantages CBCT-derived images have over conventional CT [20]. The ability to obtain reliable and accurate measurement data is perhaps the most important criterion upon which to evaluate any measurement technology.

Analysis of the Frontal Sinus in Forensic Investigation

Human identification is not a difficult work, when it is about a live individual or a cadaver chronologically recent and intact. But, when there is not a complete skeleton, a group of bones, a bone alone or just part of it, the identification process becomes progressively harder and sometimes impossible to be accomplished [21]. The anthropological knowledge is of great importance for the identification of human skeletons. Frequently, when a heap of bones is found, not all bones are present and many times only the cranium [22] is found, which can be the principal anatomic structure to be used to identify individuals [23]. Often, forensic doctors or dental surgeons are called to provide clarification to the court of justice about the origin and classification of the bone material found. In these cases, it becomes necessary to carry out a reconstructive or total identification. An identification tool to be used when reliable means are not available, is the comparison between old and recent radiographs belonging to the individual under suspicion. The X- rays of cranium, face, long bones and tooth have been the most used ones. Among them, face X-rays are better considered to forensic identification, particularly because of the presence of frontal and maxillary sinuses whose geometrical contours allow a precise superimposition into an identity [24] Nevertheless, the radiographies used for comparison may show incompatibility due to processing or storage errors or even in the direction of the beam during exposure. These events can make the investigation process difficult, bringing up doubts regarding the identification of the missing person. With the development of computed tomography - which shows higher precision to diagnose traumas of cranium - the number of image requests by professionals has increased, making possible the use of this technique to support human identification by comparing images of the frontal sinuses as well as those of other anatomical structures of the cranium. The images obtained can be filed and retrieved at an opportune moment [25]. Therefore, it is necessary for the professional to request the inclusion of the frontal sinus region in the exam.

Analysis of Bite Marks on Food Stuff

Bite mark evidence found on victim and on objects may be of great importance in criminal investigations [26]. Both the bite mark and the dentition that inflicts it are three-dimensional phenomena [27]. The bi-dimensional registration of 3D structures implies distortion and loss of information [28]. However, the

majority of the scientific community continues to describe and quantify the bite patterns in two dimensions [27]. The recent development of three-dimensional methods for bite mark analysis has become a highlighted procedure when compared to the traditional methods. Bite marks are also influenced by the pressure of the bite, the anatomy of the body part or the shape of the object. These factors determine which teeth will be involved in the bite mark and the dental surface that is marked onto the object. The procedure for comparing bite marks is well established [29]and includes measurement and analysis of the pattern, size, and shape of teeth against similar characteristics mark left on the object. There are three factors of 3-dimensionality involved when one person bites: the curvature of the object, the shape of the biting dentition and the depth of the penetration. The injury, as it is being inflicted, is a 3-dimensional event-the object deforms to accommodate the shape of the teeth. If the force of the bite is great enough to leave an indentation in the object, then the mark is also 3-dimensional. Cone Beam Computed Tomography (CBCT), specially developed for the imaging of the structures pertinent to dentistry, uses relatively small equipment, with lower costs and lower radiation doses (15 times lower) than a conventional CT [30]. The images are obtained in series of DICOM files (Digital Imaging and Communication in Medicine) that can be analyzed through several different software suites [31]. The advantage of using 3D-CBCT over the conventional technique for bite registration is the minimal handling of the object in turn minimal changes in the original bite pattern found at the crime scene. Thus CBCT has an edge over the conventional recording of the bite pattern.

Discussion

Age estimation is one of the main data that aid in human identification process. The dental changes quantification generally had used destructive methods such as the extraction and sectioning of the tooth that are unsuitable in living subjects and even for specific religious, cultural, or scientific reasons. Therefore, conservative techniques for age estimation like two dimensional images (conventional radiography) and mainly three dimensional images (CT) have been most studied [31]. CT has been gradually accepted due to aid and the potential replacement from conventional radiography by reproducing and augmenting of the information available. This has generated suitable resolution and high quality image reconstructions in multiple planes and three dimensional modeling of slices. Hard tissues images like teeth and bones are assessed using CT in any plane without invasive procedures, offering considerable practical and aesthetic benefits [32]. The other reviewed studies calculated the ratio between pulp volume and tooth volume [32-39]. The choice of this method is due to the perception of the reduction of the pulp chamber volume concerning to deposition of secondary dentin related to age in radiological images like radiographs and CT [40-46]. The identification process compares characters, looking for coincidences among past and current data. In other words, identification is a set of diversified procedures to individualize a person or object and is of great importance not only for juridical purposes, but also for the social and affective aspects involved [47]. The frontal sinus characteristics and its applicability for criminal investigations have been studied for many years, particularly in edentulous individuals [48]. Its use in successful identifications has been widely accepted by anthropologists, radiologists, pathologists and the court of justice as judicial evidence with scientific validity [49]. 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 [49]. It has been proven that there are not two people with the same frontal sinuses, even being monozygotic twins [50]. The use of cone-beam computed tomography stands out because the patient is benefited with low-dose radiation exposure compared with that for obtaining images in helical CT scanners [49]. This fact can favor doctors and dental surgeons to indicate this method to obtain tomographic images of the face.The 3D measurements on a computer-generated surface model created from a CBCT data set were accurate, and reproducibility was excellent when compared with direct anthropometry. The introduction of maxillofacial CBCT equipment provides clinicians with an opportunity to generate 3D volumetric renderings using third-party personal computer–based software [51]. Cone-beam CT can become a rich source of data for forensic investigations, taking into account that it has become more accessible for the population.

Conclusion

The computed tomography use to estimate age through dental age estimation methods and calculations to obtain the ratio between pulp volume and tooth volume displays significant accuracy.The frontal sinuses can provide significant evidence for

forensic identification. The peculiarity of the frontal sinus contours allows a precise and meticulous analysis, reducing the risk of errors on the part of the forensic experts. 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 greater reliability.As crimes have become increasingly sophisticated, new forensic investigation techniques need to be improved and developed following the emergence of new technological resources.

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