Forensic Science International 271 (2017) 68–74

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Technical Note

Guidelines for reproducing geometrical aspects of intra-oral radiographs images on cone-beam computed tomography

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ARTICLE INFO

Article history:
Received 12 May 2016
Received in revised form 17 October 2016
Accepted 12 December 2016
Available online 22 December 2016

Keywords:
Forensic dentistry
Human Identification
Cone-beam computed tomography
Radiography

ABSTRACT

Human identification requires comparison of individual traits of a person, depending on the availability and reproduction of antemortem (AM) records. If there is no presumed identity or AM exams are not available for comparison, the production of postmortem (PM) records is impaired. The purpose of this research is to describe and test standards to enable the comparison of antemortem periapical radiographs to images extracted from the manipulation of postmortem CBCT exams in multiple identification simulations in a randomized blind study. In a simulation, 20 CBCT images from dry skulls were used as PM records and 3 periapical radiographs (total of 60) that were randomized and blinded from the first examiner. In each case, an intentional incidence error of 10° was added in four different directions. Three points were selected in the AM radiograph, and the angle, linear measurements and proportion between these distances were collected. The AM data were used to mathematically find similar image geometry on a CBCT maximum intensity projection. Possible identification by superimposition was achieved in all cases, and statistical analysis proved the success in the reproduction of angular and length proportion using CBCT incidence manipulation. Significant reproducibility was also observed on intra- and inter-observer tests. In conclusion, the images extracted from CBCT could be compared to any periapical radiographs by superimposition, providing acceptable evidence to establish human identification. The application of this protocol is suitable for forensic practices with the high level of reproducibility and could be used as PM record when no AM records are available at the time of the exam.

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1. Introduction

Human identification requires procedures to individualize a person, which is an important task for legal, social, and personal matters [1]. In this context, dentistry can contribute with reliable and specialized techniques. Comparison of dental records aims to collate the particular anatomical and dental details from antemortem information, which is frequently presented by relatives, to postmortem records and images produced during the forensic examination [2]. This method is well accepted in court and has extensive scientific data available to support its usage [3,4]. Due to its ability to return fast, precise and low-cost results, the International Criminal Police Organization (INTERPOL) consider it a primary method as well as DNA and fingerprint comparison methods [4].

The use of oral radiography has been considered good clinical practice in the past decades and is broadly used in dentistry due to its importance in diagnosis [5]. Therefore, dentistry is well known for reliable production and maintenance of patient's records [1,3,6]. Digital exams are gaining ground because of image quality and the possibility of enhancements and adjustments by proper software [7,8].

The premise of forensic radiographic identification is to repeat the antemortem (AM) record in a postmortem (PM) exam. Concerning radiographs, the resulting images suffer great changes due to positioning and angle of incidence [9]. Therefore, in the PM exam, it is important to capture the same anatomical region and

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http://dx.doi.org/10.1016/j.forsciint.2016.12.015
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approximate the angle of the X-ray beam in relation to the structures to obtain similar images suitable for superimposition and comparison [3,9–11].

Despite the applicability of forensic radiographic identification, it is only possible to achieve an outcome if AM records are in fact available [2,3]. Dental charts and especially radiographs can offer important information of dental history and individual anatomical traits [3] that are usually stored for long periods of time [6]. Therefore, although the role of the forensic dentistry team's knowledge and experience is substantial, the analysis also relies on the general clinicians good practice to keep those records organized and available [2].

If presumed identities are not established during an identification exam, only secondary methods, such as facial reconstruction, can be applied [12]. Otherwise, it is common for the remains to be buried as unidentified. There is a significant number of missing people reported every day in major cities throughout the world. If an eventual suspect is found, exhumation process may be necessary to allow further investigations [13], which requires additional time and cost and is subjected to human error from body description to the location of a body. Disaster victim identification (DVI) situations are particularly exposed to such difficulties, which also includes finding the AM in time to avoid natural decay of the bodies and potential contamination risks [14].

The advance of computer sciences in the 1980s allowed refined forensic comparison with the aid of software and image editors [15]. Recent studies [16] have tested the efficacy of the use of Cone Beam Computed Tomography (CBCT) for forensic purposes. Indirect volume rendering, such as maximum intensity projection (MIP), can return images similar to regular radiographs through the creation of a 2D view of a region of interest (ROI) based on calculation of the highest-density voxel in a linear path that can be adjusted as an imaginary X-ray beam [17].

Among the different kinds of computed tomography, CBCT is suitable for the analysis of bone, tooth and dental material that is important to forensic exams [16]. In dry skulls it is possible to obtain good-quality CBCT exposures with adequate support and positioning [18].

The purpose of this research is to describe and test standards to enable the comparison of antemortem periapical radiographs to images extracted from the manipulation of postmortem CBCT exams in multiple identification simulations in a randomized blind study.

2. Methods

To achieve a level of similarity between the AM regular radiograph and the resulting view of in a cone-beam computed tomography (CBCT) exam, we propose a series of steps:

(1) CBCT acquisition and postmortem record,
(2) Analysis of the AM image and quantitative references,
(3) CBCT selection and adjustment of the point of view, based on AM references and
(4) Superimposition.

2.1. Ethics

Twenty adult human dry skulls from a Brazilian sample were selected from an existing collection of the anthropology and forensic dentistry laboratory (OFLAB) of the University of São Paulo. The project was approved by the university's ethics in research committee under protocol number 43751115.6.0000.0075, and all authorizations were granted and stored. A CBCT unity was also made available in periods that could not jeopardize the service of the general public.

2.2. CBCT and postmortem records

The voxel size is relevant, as the best definition is achieved with smaller field of view (FOV) and voxel values [19,20]. In this test, better results were correlated to smaller *voxels*.

The postmortem CBCT exams in this report were made with a R100 unit (J. Morita Corp. Tokyo, Japan) with a FOV of 80 $\times$ 80 mm. To examine the dry skulls, a preset of 75 kV and 5 mA was selected with a voxel size of 0.125 mm and a 9.6-s exposure time. The images were reconstructed in iDiexel software (J. Morita Corp. Tokyo, Japan) with an isometric voxel size of 0.125 mm. The images acquired were exported in digital imaging and communications in medicine (DICOM) files to a CD or hard drive. The lowest kV and mA presets were chosen, as there was no need for soft-tissue barriers. A head-positioning device [18] was used to keep the skulls in position.

It was important to keep the mandibular teeth a few millimeters away from the maxillary teeth. If exposed in normal occlusion, future comparisons may be impossible due to the superimposition of the upper and lower teeth and possible image artifacts.

2.3. Analysis of the AM image and quantitative references

The AM periapical radiographs can be viewed with Adobe Photoshop (Version: 2015.1.2 20160113.r.355), and a sharpen mask filter was applied.

Three visible anatomical structures should be identified and marked with a reference point made with the brush tool in a new layer.

The image must be re-scaled using the 4-cm width of the film as a reference in the analysis tool. With the scale in millimeters, the ruler tool can be used to measure the two actual distances and the angle formed between the three selected points (Fig. 1A and B).

The proportions between the longer (L1) and shorter (L2) distances can be calculated with a "rule-of-three" equation. The preference for a percentage value was idealized due to distortions, which are common on radiographs.

2.4. CBCT selection and manipulation of the point of view based on AM references

DICOM files are imported to the OsiriX® viewer. A curved multiplanar reconstruction (curved MPR) provided a panoramic view, which is helpful to assess the level of similarity and locate the region of interests (ROI) in the volume to be analyzed. If it resembles the radiograph region and anatomy, one should try to repeat the incidence of the AM image by manipulating the point of view in linear 3D MPR sagittal views.

With the principle of the well-known Clark's technique [21], the structures of different depths in a volume will change their relationships with each other if the incidence angle is changed. Therefore, to repeat a radiograph image, this dynamic can be applied to search for the same geometry between structures in the resulting image, as analyzed in the AM image. For better results, the landmarks chosen in the AM films should be root apices, cusps and other identifiable prominences of different volume depths.

In the DICOM viewer's 3D MPR, it is possible to place ROI markers in the structure's actual position in the volume. To perform this step, one must locate the correct tooth, adjusting the position of reference planes to coincide with the long axis of the tooth or root. By scrolling through the axial slices, it is possible to find the summit of the selected structure and place a marker.

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