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Human identification by FSS system adapted to cephalometric radiographs

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ABSTRACT

The aim of this study was to verify the applicability and reproducibility of the FSS system [8] adapted for frontal and lateral cephalometric radiographs of the frontal sinus for human identification purposes. Eighty lateral and frontal digital cephalometric radiographs from a private Dental Radiology service's database were evaluated. Evaluations were performed in a dimmed lighting room, using a 4.200 lux lightbox with mask, ultrafan paper and pencil with a 0.5 diameter tip. The sheet of paper was superimposed on the radiograph to obtain the outlines of the frontal sinus and two examiners made the drawings independently at two different times, with a minimum period interval between evaluations. To obtain the linear physical measurements of the frontal sinus, a digital pachymeter was used. Later, all the discrete variables were codded for the statistical analysis. All variables were tested by means of the Cohen's Kappa test. The intraexaminer agreement ranged from good to perfect ($p < 0.001$), while the interexaminer agreement ranged from regular to perfect ($p < 0.001$). The use of frontal and lateral cephalometric radiographs was found to be reproducible and reliable for human identification by an adaptation of FSS system.

1. Introduction

The identification of human remains is essential in modern societies for legal and ethical reasons. The identification of unknown bodies is often started before determining the cause of death [1,2].

Biometric methods based on physical characteristics have been proposed for human identification. However, these parameters may not be present for identification *post-mortem*, primarily in mass disasters, where the bodies have action of mechanical, physical and/or chemical agents. The methods used by forensic dentistry become quite valuable in these cases [3,4].

The sinuses of the face are pneumatic cavities existent in some bones of the cranium, which are directly related to the nasal cavity. The nomenclature of these anatomic repairs is given according to the bones in which they are located. The frontal sinuses are bilateral anatomic structures anterior to the ethmoid bone and are unique in each individual, even in monozigotic twins, as are the digital impressions. They extend for a variable distance between the exterior and interior of the frontal bone of the bone plates, and sometimes penetrate into the orbital plates. They are pneumatic cavities either separated by a septum or not. [5].

Evaluation of the frontal sinuses as a human identification method has strong backing in forensic anthropology due to the fact of these structures being absent in only 4% of the population [6] and having morphological variations in every individual [5,7–10]. Anatomically, the frontal sinuses appear by age 1 and grow larger

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in size after puberty, attaining their almost maximum size at age 20, and remain stable until further enlargement of the chambers can occur due to bone resorption during the advanced ages [2,11]. The individuality of their outlines allows precise and meticulous analysis, thus diminishing the risks of errors during personal identification [12].

Radiology is considered an individual identification means given radiographs from different structures of the human body offer the features of individuality and immutability [4]. Verification of identity using the frontal sinuses has been performed by trying to compare *ante-mortem* radiographs with those taken *post-mortem* [6,11,13]. Various studies have used the frontal sinuses for the purpose of identifying humans by means of extraoral radiographs [6,11,14–16] and by computed tomography [7,9,10,17–19].

To minimize possible false-negative human identifications and to determine objective criteria in radiographic images or tomography of the frontal sinuses, some researchers have proposed classification systems [8,10,20]. Among these classification systems, there is the FSS system proposed by Tatlisumak et al. [8]. This method was applied in tridimensional images obtained using Multislice Computed Tomography, and is based on the application of a system that evaluates three basic features, namely F (presence or absence of frontal sinus), S (septum) and S (scalloping). Greater identification was verified when new evaluation parameters were added [8]. However, probability of an individual being submitted to conventional extraoral radiographic images antemortem is greater than a computed tomography. There are no data in the literature with regard to evaluation of the reliability of the FSS system in human identification using both lateral and frontal view cephalometric radiographs.

Considering the high number of patients that some time in their life are submitted to orthodontic treatments and use analyses based on lateral and frontal cephalometric radiographs for diagnosis and treatment following, antemortem radiograph can be available for a victim, mainly in mass disasters. Additionally, it is necessary reliable, low cost, and easily reproducible methods for human identification. Therefore, the aim of the present study was to evaluate the applicability of the FSS system in addition to the criteria included by the authors of the present article, using printed digital frontal and lateral cephalometric radiographic images of individuals.

2. Materials and methods

The Ethics Committee of the University of Pernambuco (Protocol CEP/UPE No.250/11 CAAE: 0254.0/097,000-11) approved the study. Eighty frontal and 80 lateral cephalometric radiographs of patients attending at a private dental radiology service were retrieved from the computer database and assessed.

Patients aging 20 years old or higher who underwent acquisition of both lateral and frontal cephalometric radiographs on the same date with frontal sinuses within the aspects of normality were selected to the sample. Patients with radiographic evidences and/or medical history of fractures, pathologies or perforations that compromised radiographic evaluation of the frontal sinus were excluded from the sample.

The radiographic images were made using KODAK 8000C Digital Panoramic and Cephalometric Extraoral Imaging System (Eastman Kodak, Rochester, NY). The distance from the mid-sagittal plane of the patient to the X-ray source was fixed at 1.52 m. The Frankfurt horizontal plane was parallel to the floor. The teeth were placed in occlusion and with lips relaxed or on reposed position. Exposure parameters (Kilovolt, Milliampere and Second) for the radiological image acquisition were selected according with the patient's age and morphology.

The radiographic images were printed using Drystar Agfa $8 \times 10''$ film (Dry Medical Film – Mortsel, Belgium) by the thermal Drystar Agfa printer (Drystar 4500-Mortsel, Belgium) after size calibration.

2.1. Radiographic evaluation

The images were assessed by two independent, previously calibrated, evaluators to determine the reliability and reproducibility of the qualitative and quantitative variables. Written and verbal instructions were made available to the observers prior to all examination sessions. Kappa's Cohen test was performed to determine the reliability and reproducibility of the evaluations.

Initially, for the calibration phase, the evaluators assessed twenty images, following the same inclusion and exclusion criteria, of patients who did not form part of the sample (ten for each radiographic technique – frontal cephalometric and lateral cephalometric radiography) using the FSS system at two different times with a 15 minimum days interval. The calibration lasted four weeks and, to guarantee reproducibility of the study, intra and interexaminer agreement were made using the Cohen's Kappa test. Evaluation of the study images began after obtaining a Kappa index that ranged between 0.81 and 0.99 (excellent).

Two examiners assessed the radiographs at two different times, with a four weeks minimum interval between evaluations. To avoid visual fatigue, a maximum of ten images per day was established. Evaluation was performed in a quiet room with dimmed light and with the aid of a 4.200 lux lightbox with mask, ultrafan paper and pencil with a 0.5 diameter tip. The sheet of paper was superimposed on the radiograph to obtain the outlines of the frontal sinus. Measurements on the radiographs were obtained with the use of a high precision digital pachymeter Mitutoyo series 167 (Mitutoyo Sul Americana, Suzano, Brazil). An adaptation of the FSS system, established by Tatlisumak et al. [8], was performed with the analysis of the variables shown on Table 1.

All parameters were recorded on an evaluation sheet for each patient. The inferior border of the frontal sinus was drawn tangential to the upper margin of the orbits. This was determined for the current study because it is reliable and an accepted methodology [13,21,22].

All the measurements were coded according Tatlisumak et al. [8] method. Thus, for width and height $0 < x \leq 15$ mm was scored with 1, $15 < x \leq 30$ mm with 2 and $30\text{ mm} < x$ with 3. For anteroposterior length, distance between the highest point of the right sinus and the right lateral maximum limit and distance between the highest point of the left sinus and the left lateral maximum limit measurements between $0 < x \leq 10$ mm were scored with 1, $10 < x \leq 20$ mm with 2 and $20\text{ mm} < x$ with 3. For the total width of sinuses and total width of sinuses, distance between the highest points of the right and left sinuses $0 < x \leq 30$ mm were coded with 1, $30 < x \leq 60$ mm were with 2 and $60\text{ mm} < x$ with 3. When the absence of a sinus, the measurement was not made and was the coded as zero.

For evaluation of the variables, the following criteria were adopted: any pneumatization visible in the radiographs was considered the presence of sinus; in case of absence of intersinus septum, the sinuses were considered as one; it was considered a complete septum those that went from one sinus limit to the other and incomplete the ones that did not followed this rule; deviation of the intersinus septum was considered when the inclination exceeded 5 mm; when apparently there were two intersinus septum, the most medial septum was considered; in cases of superimposition of the crest on the intersinus septum, the center of the crest was considered for taking the measurements; the