Int. J. Odontostomat.,
16(3):352-358, 2022.

Human Identification by Comparative Analysis of Frontal Sinuses: Study on Computed Tomography

Identificación Humana por Análisis Comparativo de Senos Frontales: Estudio en Tomografía Computarizada

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ABSTRACT: Generally, primary methods of identification as the fingerprint analysis, dental analysis or DNA examination are indicated for the establishment of the identity of a corpse. In situations with poor body conservation, such as in advanced stage of putrefaction or skeletonization, imaging exams like medical and dental computed tomography can assist in the process of identification. The frontal sinuses present anatomical characteristics that allow the establishment of the identity of an individual. In this case report we used the technique of three-dimensional construction of the frontal sinuses through the generation of solid figures representative of the sinus morphology. After the comparative analysis of the antemortem and postmortem tomography of the alleged victim, we could establish similarities in both the variations in size, shape, symmetry and contour of borders, and the presence and number of septa, allowing us to infer that the two images described belong to the same individual, thus establishing the identity of the corpse found.

KEY WORDS: forensic anthropology, cone-beam computed tomography, skull, frontal sinus.

INTRODUCTION

An individual's identity can be established by using primary methods such as fingerprinting, dental characteristics and DNA analysis (INTERPOL, 2018). These reliable methods allow the identification by comparison between person's data collected during its lifetime and cadaveric data.

The establishment of an identity can be hindered by the intentional removal of fingers and teeth by groups who practice organized crime, in cases with humans remains decomposed or burnt that may not allowed the analysis of these elements and in situations where only fragments of skull exist (Patil *et al*., 2012; Cameriere *et al*., 2020).

Thus, the attributions of the team of forensic dentists have expanded and new methods have been presented to establish identities. The radiographic comparison of osteological structures has been commonly used to confirm identification of human remains (Belaldavar *et al*., 2014).

The cone-beam computed tomography has been frequently used since the emergence of implants.

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Received: 2022-04-08 Accepted: 2022-06-22

In this way, the possibility of individuals having a computed tomography with their dental records is a fact, making possible the analysis of different bone structures, such as frontal sinuses.

This article aims to report the identification of a corpse presenting complete edentulism, using the analysis and comparison of the internal volume of the anatomical structures of the frontal sinuses through antemortem and postmortem computed tomographies.

CASE REPORT

An unidentified corpse was found in the banks of a stream in the city of Piracicaba, State of São Paulo, Brazil, in an advanced state of putrefaction/ skeletonization (Fig. 1). The corpse was first transported to the Legal Medical Institute of the city and then was transferred to a team of forensic dentists from the School of Dentistry of Piracicaba/UNICAMP for anthropological examinations and the establishment of the identity.

Anthropological Examination. For anthropological examination, after the bones were properly cleaned, the team performed some photographic records (Fig. 2) and a general physical examination of the skull revealed individualized characteristics (Table I).

Fig. 1 Unknown corpse in an advanced state of putrefaction.

The anthropological study, in general begins with the determination of gender and it was done using qualitative and quantitative methods (Loth & Henneberg, 1996; Rogers, 2005; Saini *et al*., 2011), analyzing dimorphic structural bone aspects and measurements of the skull and pelvis, respectively, stating a predominance of male characteristics.

Subsequently, the age was estimated by the loss of sutural interdigitations (Fig. 2B), and we found that was a skull of an individual aged over 50 years.

The determination of ancestry was done using the qualitative method with the direct observation of the nasal aperture, which showed a mesorrhine nose, indicating a mixed-race individual (brown skin). It was also used a quantitative method with the nasal index (Fig. 2A), characterizing the individual as caucasian, according to the Brazilian Table (Vanrell, 2019). This situation is completely understandable considering that the Brazilian Caucasian has a high miscegenation with black individuals, thus generating brown individuals.

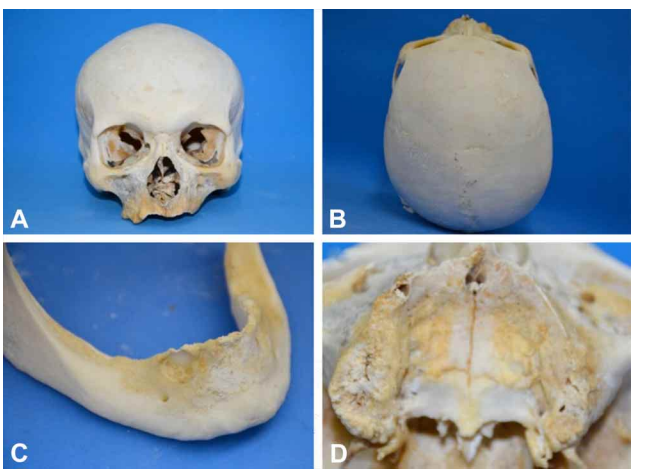

Fig. 2 Photographic records of the skull in front view (A); the skull in top view (B); the mandible with the lesion in the rounded mandibular border with regular borders (C); the maxilla with the alveolus in reparation (D).

The estimation of stature from the skull was not performed because of the absence of teeth, which makes the application of the method developed by Carrea cited by Lima *et al*. (2011) unfeasible.

Table I. Individualized characteristics of the skull during postmortem exam.

CHARACTERISTIC
Widespread absence of dental crowns
Dental alveolus in repair in the region of the upper right premolar, suggestive of recent dental extraction
Cavity bone lesion in the region of the lower right premolar, suggestive of cystic lesion
Residual dental root of the lower left premolar

INTERPOL (2018) established that anthropometry, although indicating gender, age, ancestry and stature, does not allow the establishment of the identity of the individual, but it can contribute to eliminating possible suspects.

Imaging Exams. With the anthropometric data obtained we were left with a family that was looking for a family member, which will be referred to as "alleged victim". The family presented a computed tomography of the skull of the alleged victim (Fig. 3A) from two years before derived from a stroke accident. For comparison with this tomography, the team of forensic dentists obtained a cone-beam computed tomography from the cadaver, covering the region of the frontal sinus (Fig. 3B).

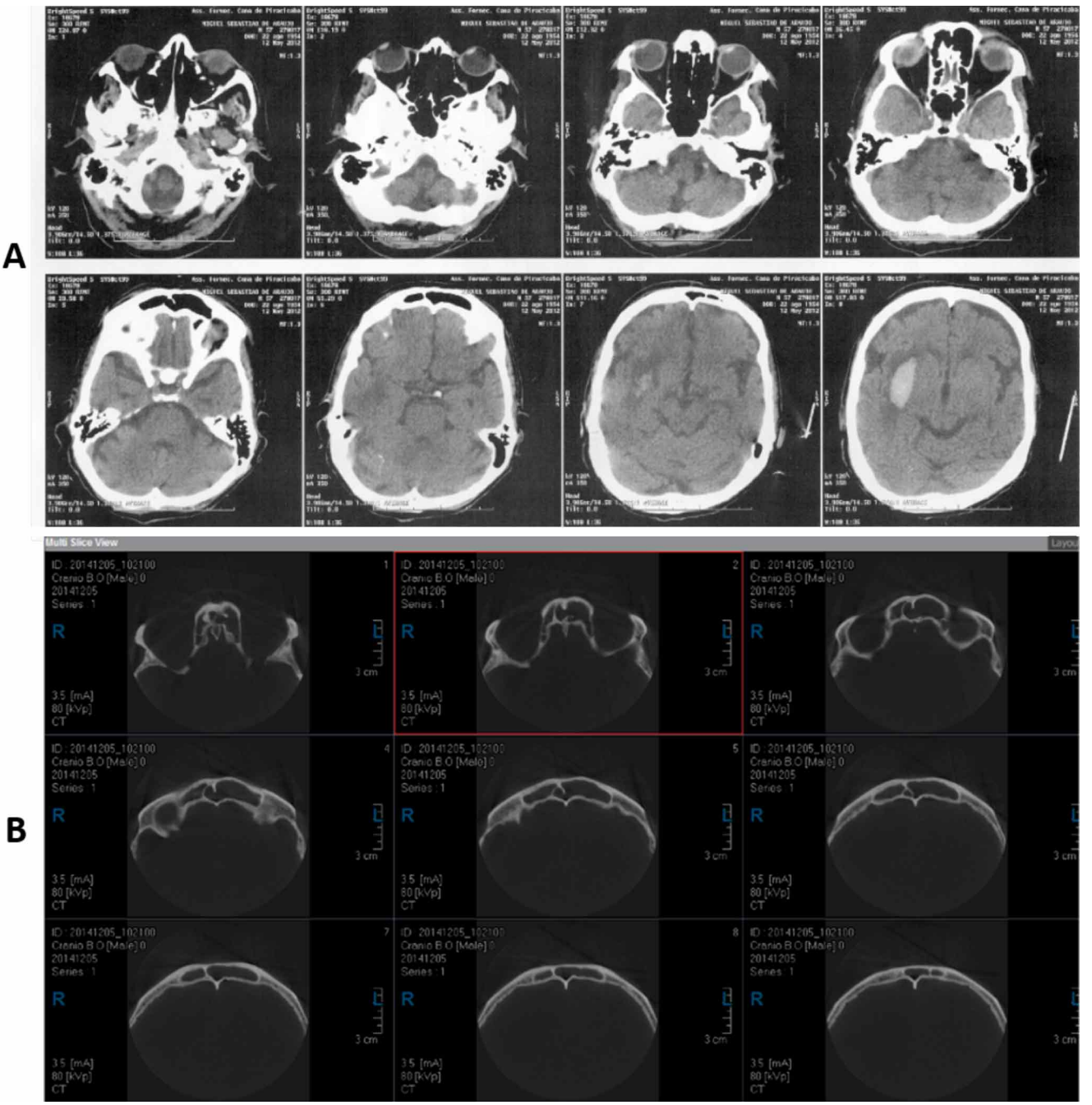

Fig. 3 Axial cuts of the antemortem tomography (A); Axial cuts of the postmortem tomography (B).

The team also performed a panoramic radiography of the cadaver (Fig. 4), being observed in the region of the lower right premolar a radiolucent area in an arc, with well-defined cortical bone, suggesting a recent tooth extraction. Also on the right side, in the region of lower premolars, a rounded radiolucent lesion with well-defined edges was noted, which suggests a cystic lesion; however, a radiographic confrontation of this region was not possible.

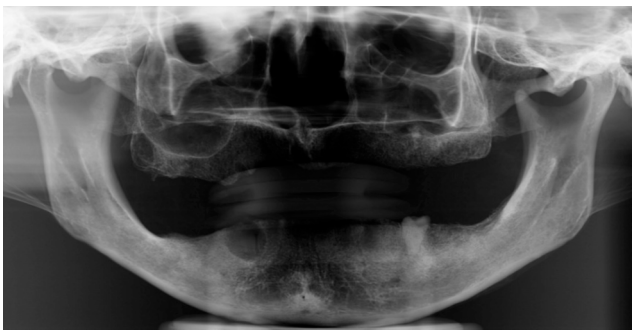

Fig. 4 The postmortem panoramic radiography.

Three-dimensional Overlap of Cavity Structures. To perform the morphological comparison between the frontal sinus structures obtained from the antemortem and postmortem tomographies, we used the ITK-SNAP segmentation software (Cognitica, Philadelphia, PA) (Yushkevich *et al*., 2006). The antemortem image was a multislice tomography of the skull (Brightspeed S, GE Medical Systems, UK), with 247 DICOM images of 0.5 mm^3 in thickness. And the postmortem tomography was obtained by a cone-beam computed tomography (Picasso-Trio, Vatech America, USA), with 424 DICOM and voxel images of 0.20 mm^3 from the dry skull.

The DICOM images from the two tomographies were adjusted at +76 and +62, respectively, to highlight the sinus structures (CD 3D Imaging, Carestream), and the brightness and contrast of the image were adjusted in the postmortem tomography with window 3122, minimum input intensity level of -945 and maximum of 2192.

The region of interest was delimited by the maximum width of the sinus in front view in the coronal section, from the anterior aspect of the glabella up to the medial wall of the sella turcica in the sagittal section, and from the upper apex of the sinus up to the rinion craniometric point observing the axial section.

The method chosen was the image edge with the parameters sigma 1.6, kappa 0.156 and edge mapping exponent at 2.80.

In the sinus cavity structure of interest we inserted "bubbles" throughout the whole (empty) structure of interest without touching the bone structures (adjacent edges); the next step was the step-by-step iteration, observing the solid structure filling the sinus shape (Fig. 5).

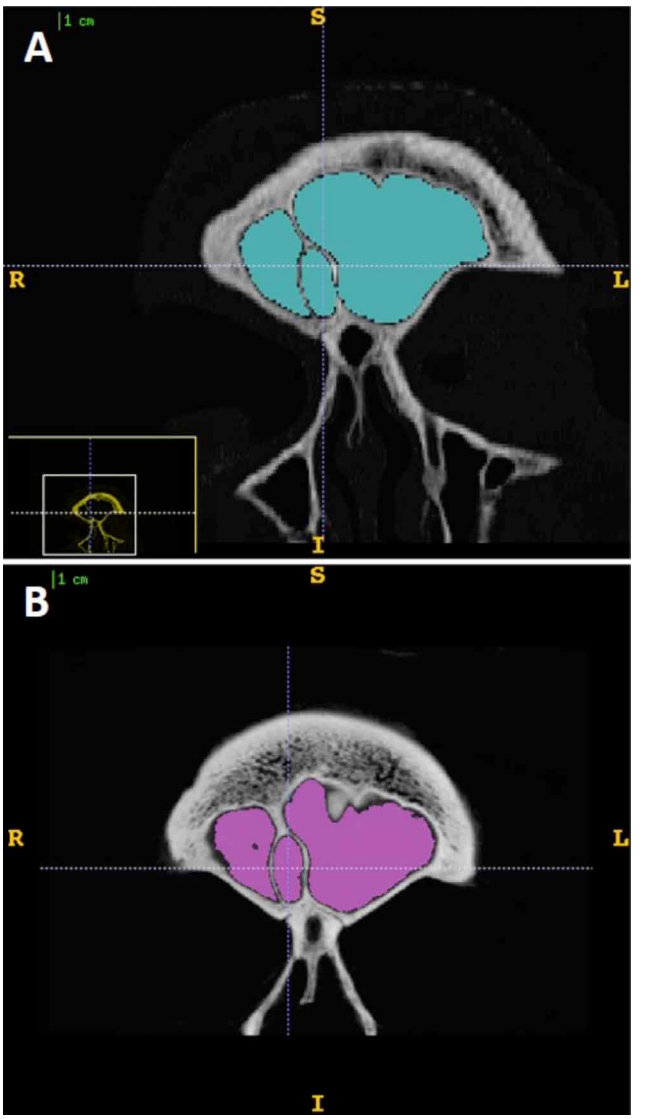

Fig. 5 Coronal tomography cuts showing the frontal sinus filled. Antemortem exam (A); Postmortem exam (B).

The three-dimensional form created from the entire sinus space filled is exported in the stereolithographic mesh format (Fig. 6) to be compared in CloudCompare®, a three-dimensional editing software, in which the two meshes were inserted and synchronized overlapping (Fig. 7), creating a new mesh with relative colors denoting the compatible structural uniqueness between the two structural forms, which indicates a positive identification.

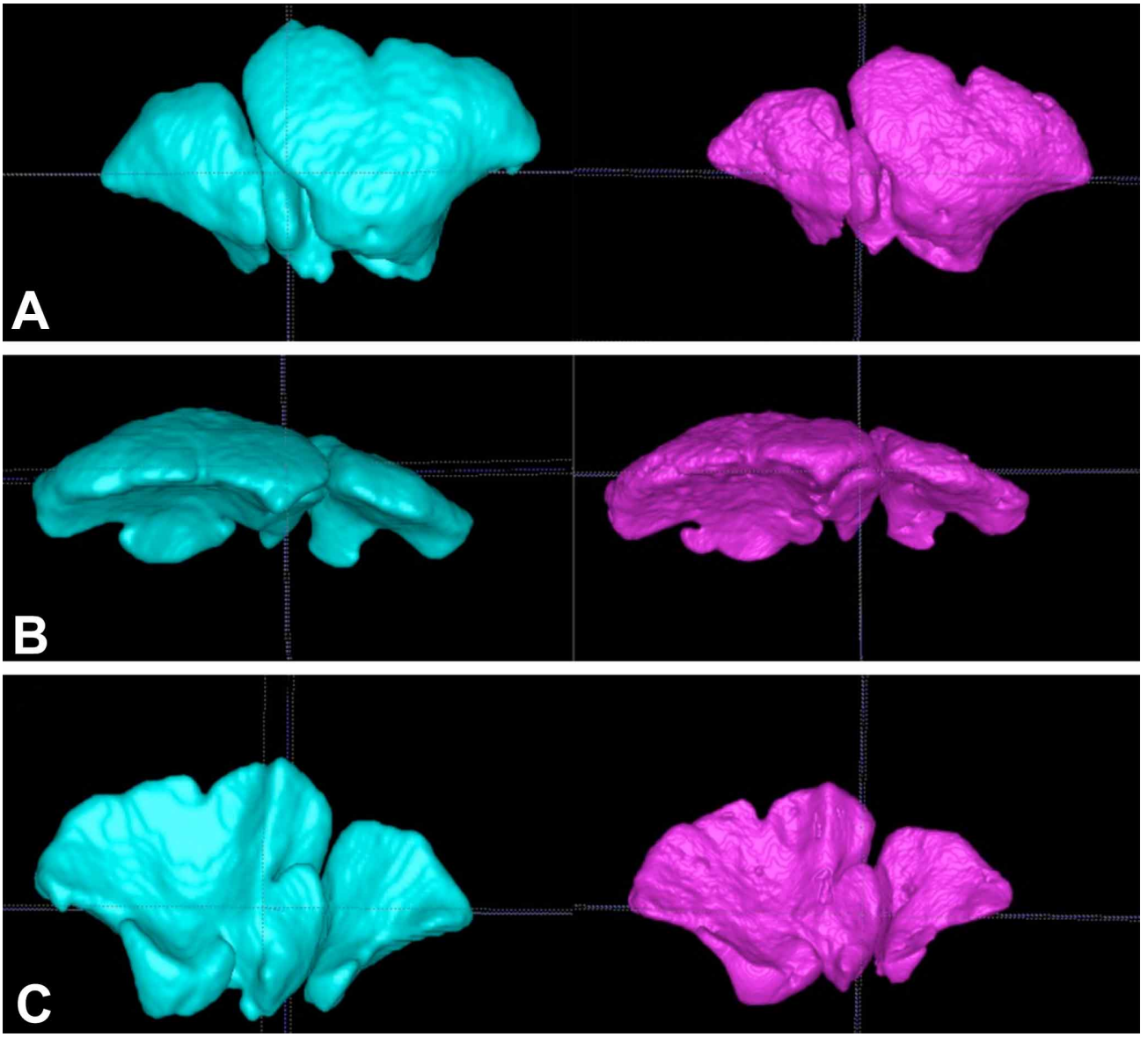

Fig. 6 Stereolithographic mesh created from the antemortem tomography in blue and from the postmortem tomography in purple. In front view (A); in top view (B); in back view (C)

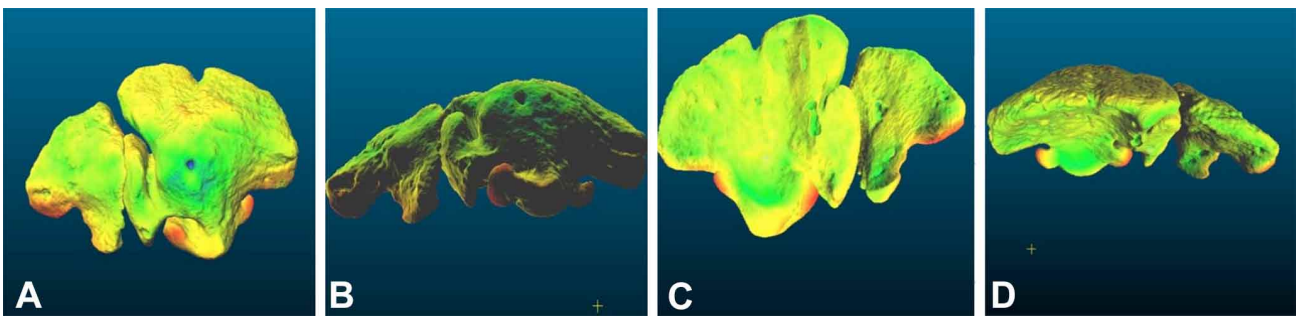

Fig. 7 Overlapping meshes. In front view (A); in bottom view (B); in back view (C); in top view (D)

DISCUSSION

The frontal sinuses are a cavity present inside the frontal bone, beginning its development at about 2-3 years of age, and defining its configuration by age 18-20 (Belaldavar *et al*., 2014; Reichs, 1993; Gadekar *et al*., 2019; Verma *et al*., 2017).

Its morphology remains unchanged through adult life (Belaldavar *et al*., 2014; Gadekar *et al*., 2019) with tremendous interindividual variation (Reichs, 1993; Michel *et al*., 2015). Analyzing 400 posteroanterior cranial radiographs, Gadekar *et al*. (2019) found different morphology of frontal sinus in each individual.

Some studies (Cameriere *et al*., 2020; Shireen *et al*., 2019; Suman *et al*., 2016) examined the frontal sinuses features giving it a score, enabling the creation of a code number for each individual. Reichs (1993) reported that due to high number of combinations possible to form the code number, the possibility of two persons having the same code number is extremely remote.

Also the absence of frontal sinus is an unusual morphologic characteristic that actually helps in the cadaver identification process. Çakur *et al*. (2011) examining scans of 410 patients found bilateral absence of frontal sinus in 0.73% of cases and unilateral absense in 1.22%.

With regard to the differences between the sexes, the studies found greater measurements of frontal sinuses in males than in females (Belaldavar *et al*., 2014; Kim *et al*., 2013; Verma *et al*., 2017; Shireen *et al*., 2019), which Michel *et al*. (2015) believe that due to the anterior projection of the glabela in males.

According to Reichs (1993) and Michel *et al*. (2015), the computed tomography must be used in detriment of bidimensional radiographs to the achievement of more reliable data from the dimension of the frontal sinuses.

The identification procedure related in this article is based on the comparison of antemortem and postmortem computed tomographies scans. And the data collected with comparative purpose are shown in Table II.

The use of a three-dimensional mesh editing tool enabled a better visualization of intracranial structures, since it has eliminated the overlap of bones that complicates and confuses the visualization. The visual inspection comparing the two meshes created was enough to satisfactorily enable identification.

To overlap the stereolithographic meshes, the new unified mesh presented red regions that indicate a misalignment originated by a deficiency in the synchronization of these meshes and also a difference in the voxel size of the tomographies used; however, this difference was not significant when comparing the morphology of the structure.

Some limitations can be found during the analysis of the frontal sinuses, as the recovery of a fragmentary skull (Kim *et al*., 2013) and the absence of radiography or CT images of the skull.

In conclusion, the comparative analysis of the antemortem tomography of the alleged victim and the postmortem one, showed similarities in both the variations in size, shape, symmetry and contour of borders, and the presence and number of septa, allowing us to infer that the two images belong to the same individual, thus establishing the positive identity of the corpse found.

ACKNOWLEDGMENTS. The authors thank the Forensic Medical Institute of Piracicaba city for allowing the dissemination of this case.

Table II. Points of anatomical coincidence between the tomography of the alleged victim and the tomography of the skull under analysis.

Tomography of Alleged Victim	Tomography of the Skull	Coincidence
Presence of 1 septum	Presence of 1 septum	Positive
Septum divides the frontal sinus into 2 complete cells	Septum divides the frontal sinus into 2 complete cells	Positive
Partial septa 0	Partial septa 0	Positive
Size of left cell presents less volume when compared with the right cell.	Size of left cell presents less volume when compared with the right cell.	Positive
Inclination of the medial portion	Inclination of the medial portion	Positive
Descending part, following the contour of the crista galli	Descending part, following the contour of the crista galli	Positive
Curvature of the bottom margin	Curvature of the bottom margin	Positive

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RESUMEN: Generalmente, los métodos primarios de identificación como el análisis dactiloscópico, el análisis dental o el examen de ADN están indicados para el establecimiento de la identidad de un cadáver. En situaciones de mala conservación del cuerpo, como en etapa avanzada de putrefacción o esqueletización, los exámenes de imagen como la tomografía computarizada médica y dental pueden ayudar en el proceso de identificación. Los senos frontales presentan características anatómicas que permiten establecer la identidad de un individuo. En este reporte de caso utilizamos la técnica de construcción tridimensional de los senos frontales a través de la generación de figuras sólidas representativas de la morfología sinusal. Tras el análisis comparativo de la tomografía antemortem y postmortem de la presunta víctima, pudimos establecer similitudes tanto en las variaciones de tamaño, forma, simetría y contorno de márgenes, como en la presencia y número de septos, lo que nos permite inferir que las dos imágenes descritas pertenecen al mismo individuo, estableciéndose así la identidad del cadáver encontrado.

PALABRAS CLAVE: antropología forense, tomografía computarizada de haz cónico, cráneo, seno frontal.

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