ISSN- 0102-9010

ANATOMO-RADIOLOGICAL AND MORPHOMETRICAL STUDY OF THE FRONTAL SINUS IN HUMANS

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ABSTRACT

An understanding of frontal sinus anatomy is important for clinical and forensic medicine. In this study, we examined the relationship between skull and sinus dimensions. Fifty human skulls were measured and radiographed in two projections (Caldwell's view and in a lateral view) to visualize the paranasal sinuses. The radiological dimensions of the frontal sinus (height, width, thickness and area) were measured using the software Autocad R 14. The possible correlations between the skull measurements and the sinus dimensions were examined. The frontal sinus was present in all specimens. The maximum dimensions of the frontal sinus included a width of 49 to 79 mm, a height of 8 to 18 mm, and an area of 0.5 to 9.5 mm^2. A significant positive correlation was observed between the sinus area and the other dimensions of sinus. Thus, increase in dimensions also increased the sinus area. A weak positive correlation was also observed between the skull height and sinus thickness, and between skull length and frontal sinus area.

Key words: Anatomy, frontal sinus, morphology, radiology, skull

INTRODUCTION

The interpretation of the radiological anatomy of the paranasal sinuses is complicated because the projection of the sinuses onto each other can reduce the anatomical details of the image and also because human sinuses show multiple variations [7]. As discussed elsewhere [8,9], there are considerable variations in the shape, capacity, and asymmetry of the frontal sinus. Hence, a knowledge of frontal sinus anatomy and its variations is important for the diagnosis of acute and chronic sinus pathologies and for clinical and surgical procedures [3,4]. In forensic medicine, the frontal sinus and other paranasal sinuses are important for establishing a reliable identification of unknown human remains based on the comparison of antemortem and postmortem radiographies [5].

Considering the importance of the frontal sinus in clinical applications, we have used radiological analyses to examine whether the variation in frontal sinus anatomy is related to certain skull dimensions, and whether these parameters could be used to predict the morphology of the sinus.

MATERIAL AND METHODS

Fifty adult human skulls of both sexes from two different ethnic groups broadly defined as white and non-white because of the high degree of miscegenation in Brazil were randomly selected from the bone museum collection of the Department of Morphology at UNIFESP (Federal University of São Paulo). The skulls were classified according the individual's age: 19-39 years (n = 20), 40-60 years (n = 23), and > 60 years (n = 7). After defining the six anthropometric points relevant to this study (Fig.1), the distances were measured with a millimeter ruler and pachymeter (1mm) and included the maximum skull length (from the glabella to the opisthocranium), the prostio-bregmatic height (from the prostium to the bregma) and maximum skull width (from one euryon to the other).

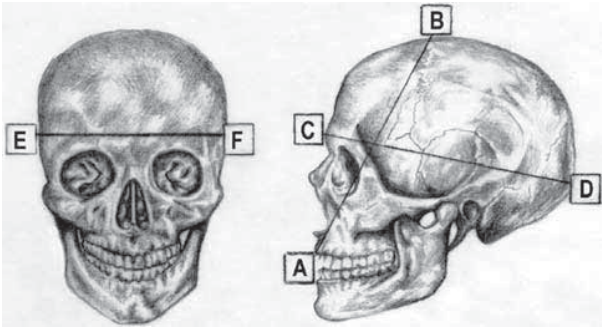

Figure 1. A-B: prostio-bregmatic height, **C-D**: maximum skull length and **E-F**: maximum skull width.

The radiological analyses of the skulls were based on two projections: Caldwell's view (occipitofrontal projection) and a lateral view, a standard X ray technique for visualizing the paranasal sinuses. Since the skulls varied in density, different values of kV and mA were used in order to obtain the same final result, i.e. the same image neatness without magnification, since the focal distance of the camera was always the same. The skulls were placed in a wooden support with adjustable screws to

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provide the best position without interference in the radiological images. The radiological outlines of the frontal sinus restricted to the level of the crista galli, were drawn with a pencil on translucent paper. These drawings were then scanned and analyzed using the software Autocad R 14 which allowed measurement of the width, height and thickness of the frontal sinuses (Fig 2).

These data were analyzed statistically using Student's t-test and Pearson's correlation. A value of $p < 0.05$ indicated significance.

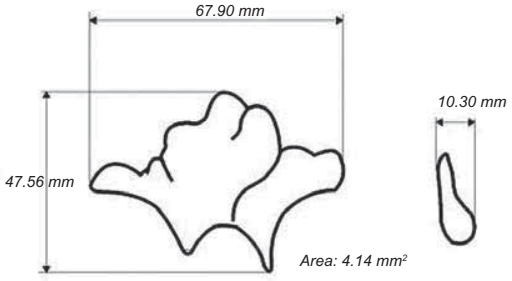

Figure 2. Example of the frontal sinus measurements obtained with Autocad R14 software. Anterior and lateral views.

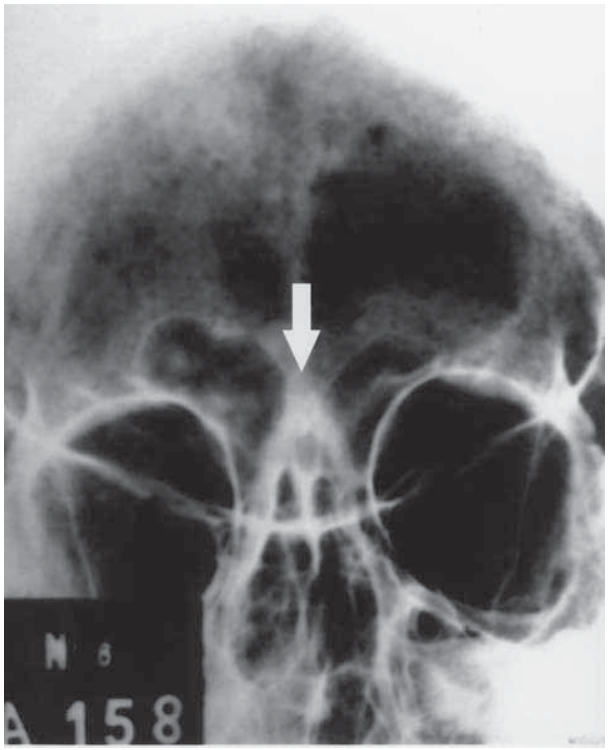

Figure 3. Bilateral isolated frontal sinus with septum directed along the midline (**arrow**). Note the pyramidal shape of the sinus.

RESULTS

The frontal sinus was observed in all of the skulls analyzed. In 18 cases (36%) there was bilateral confluence, in 30 cases (60%) the sinus was bilateral but not confluent and in 2 cases (4%) it was unilateral (Fig. 3). A septum was present in 40 cases (80%) and absent in 10 cases (20%). This septum was directed along the median line in 65% of the cases, to the right side in 22.5% and to the left side in 12.5%. An arched sinus was seen in 68% of the cases, a pyramidal sinus in 22% and no definite shape in 10% (Fig. 4). Most of the sinuses had small, incomplete septa, especially arched sinuses (Fig. 5).

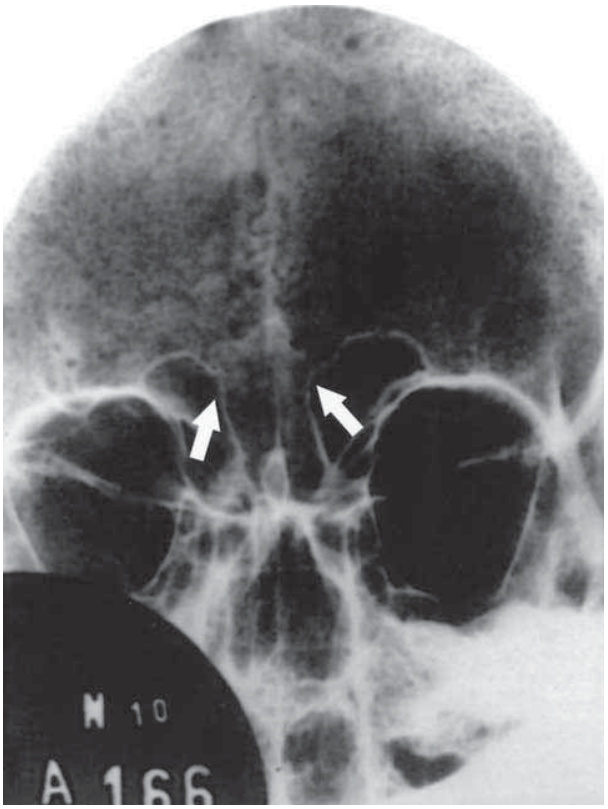

Figure 4. Bilateral isolated frontal sinus with two septa (**arrows**), showing three isolated sinuses of undefined shape.

The maximum sinus height varied from 20 to 80 mm, with most skulls (92%) measuring from 30 to 70 mm. The maximum sinus width varied from 19 to 97.8 mm, with most skulls (60%) measuring from 49 to 79 mm. The sinus thickness varied from 8 to 25.8 mm, with most skulls (78%) measuring 8 to 18 mm, and the sinus area varied from 0.5 to 13.68 mm^2, with most sinuses (90%) having an area of 3.5 to 6.5 mm^2 (Fig. 6).

A significant positive correlation was observed between frontal sinus area and the other radiological dimension ($r = 0.87$, 0.92 and 0.56 for height, width and thickness, respectively). A weaker positive correlation was observed between the skull length and

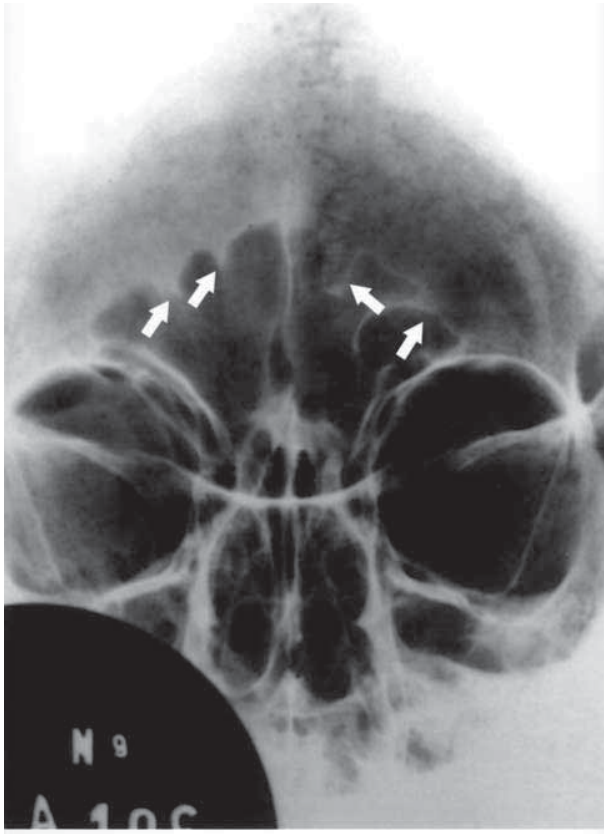

Figure 5. Bilateral isolated frontal sinus with septum directed along the midline. Note the arched shape of the sinus with small, incomplete septa surrounding the area (**arrows**).

the radiological area of the frontal sinus (r = 0.34), and between skull height and frontal sinus thickness (r = 0.32). Student's t-test applied to the independent group averages showed that there was no significant difference between the two ethnic groups studied.

DISCUSSION

Interindividual and intraindividual variations in the size and shape of the frontal sinus have been reported [7,10]. The presence of small, incomplete septa throughout the extention of some sinuses has also been observed, as has the occurrence of up to seven incisions [6,10]. Most incisions occur in arched sinuses 3-7 per sinus, with fewer in the other types of sinuses (0-3 per sinus). The average width of the frontal sinus reported by Vidic [11] was 65.8 mm. According to Weiglein [12], the average height, width and length of the frontal sinus was, respectively, 24 mm, 29 mm and 20 mm. The average height of the frontal sinus measured by Harris *et al.* [1] was 24.3 mm. In our series, the mean height, width and thickness was 45.95 mm, 25.80 mm and 14.13 mm, respectively.

Hungria [2] examined the relationship between the frontal sinus shape and capacity and the number of ethmoidal cells that had invaded the bone during sinus formation and found that skull height correlated

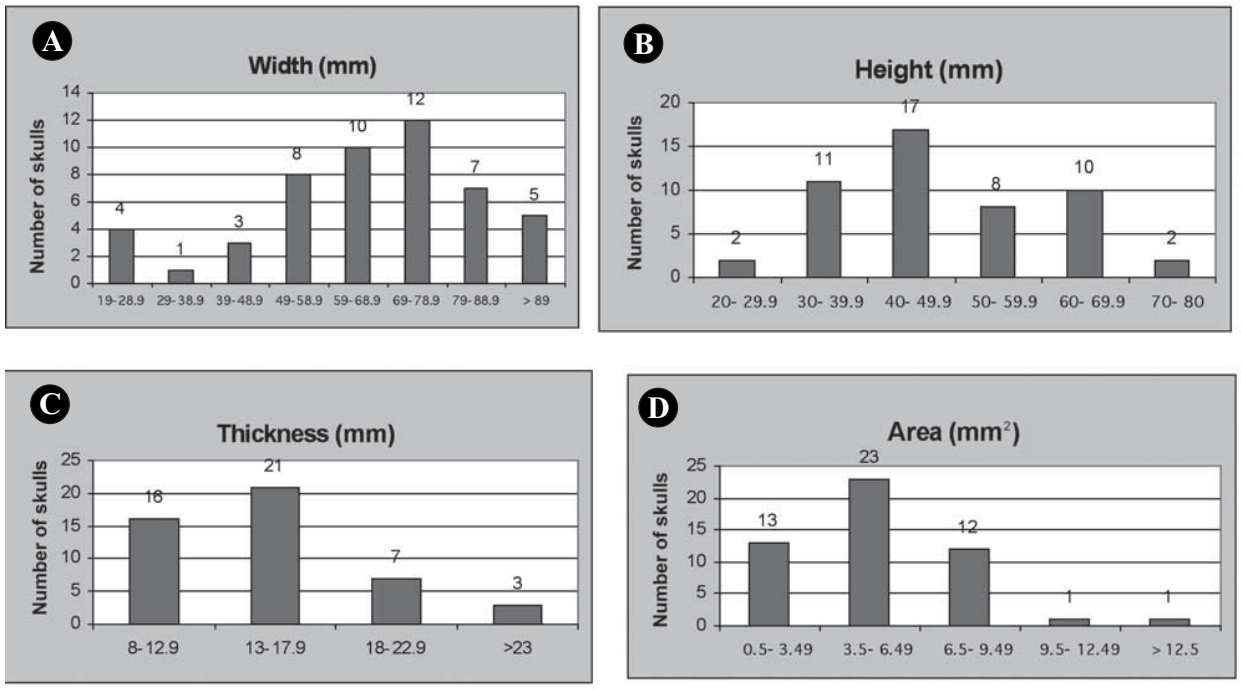

Figure 6. Frequency distributions for frontal sinus parameters (**A**) maximum width, (**B**) maximum height, (**C**) maximum thickness and (**D**) maximum area.

with the sinus thickness whereas skull length correlated with sinus area.The larger the skull length and height, the greater the space between the internal and external plates of the frontal bone.

This would allow a larger number of ethmoidal cells to migrate to this space during the formation of the frontal sinus. As a consequence, there is intense pneumatization that results in a thicker and larger sinus in adults.

There was a tendency, for the frontal sinus area to increase with age (Pearson correlation coefficient, r = 0.32). According to Nambiar *et al.* [5], this increase results from a reduction in skull thickness with age.

In conclusion, the frontal sinus is a constant structure in the human being, but its shape and dimensions may vary among individuals. A statistically significant correlation existed between the sinus area and the other dimensions of the sinus. However, the frontal sinus dimensions was weakly correlated between skull height and sinus thickness, and between skull length and frontal sinus area.

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Received: March 14, 2003
Accepted: October 31, 2003