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Study on the development of frontal sinuses by morphometric analysis of the skull

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ABSTRACT. The frontal sinuses are cranial areas of clinical, forensic and pathology importance whose development mechanisms are still poorly defined. Nasal airflow and brain development are two of the main theories. Current analysis debates whether they are the real determinants of frontal sinuses growth, which may be proved by the skull's morphometric analysis. Four groups of measures related to the external cranial architecture, the pyriform aperture, orbital cavities and frontal sinuses were defined. Thirty-three skulls of individuals, mean age 68 years, from the Laboratory of Anatomy of the Academic Centre of Victoria – UFPE – Brazil, were used. Statistical analysis showed total agenesis of the frontal sinus in 18.2% of the skulls. There was significant correlation between the development of the right frontal sinus and the pyriform aperture, and between the left frontal sinus and two cranial measurements ($p \leq 0.05$). Significant differences between mean of pyriform aperture areas of the skulls with or without sinuses were also reported ($p \leq 0.01$). Results supported the fact that there was a modulation activity by nasal aeration and brain formation in the development of frontal sinuses.

Keywords: paranasal sinuses, pyriform aperture, craniometry.

Estudo referente ao desenvolvimento dos seios frontais pela análise morfométrica do crânio

RESUMO. Os seios frontais são espaços cranianos de importância clínica, forense e patológica, cujos mecanismos responsáveis pelo desenvolvimento são ainda pouco definidos, sendo duas das teorias propostas, o fluxo aéreo nasal e o desenvolvimento encefálico. Objetivou-se evidenciar por meio de análise morfométrica do crânio se estes são os reais fatores determinantes do crescimento dos seios frontais. Neste estudo, foram definidos quatro grupos de medidas referentes à arquitetura craniana externa, à abertura piriforme, às cavidades orbitárias e aos seios frontais. Para este propósito, nós utilizamos 33 crânios de indivíduos com média de idade de 68 anos, provenientes do Laboratório de Anatomia Humana – Centro Acadêmico de Vitória- UFPE/Brasil. Após os exames estatísticos, foi verificado agenesia total dos seios frontais em 18,2 % dos crânios estudados. Houve correlação significativa entre o desenvolvimento do seio frontal direito e a abertura piriforme, e entre o do seio frontal esquerdo e duas aferições encefálicas, com $p \leq 0,05$. Observamos uma diferença significativa entre as médias de áreas de abertura piriforme dos crânios que possuíam ou não os seios, com $p \leq 0,01$. Os achados deste estudo comprovam o fato de que existe uma atividade moduladora exercida pela aeração nasal e formação encefálica no desenvolvimento dos seios frontais.

Palavras-chave: seios paranasais, abertura piriforme, craniometria.

Introduction

Frontal sinuses are part of the paranasal sinuses, or rather, pneumatic chambers located in some bones of the viscerocranium that develop as extensions of the nasal cavity's respiratory section (GRAFF; MARSHALL, 2003). These front chambers are located in the frontal bone at the glabella level, frequently extending to the supraorbital arches. They are generally asymmetrical and separated by a septum shifted from the median plane. Communication occurs through the frontal nasal duct, between each frontal sinus and ethmoidal infundibulum which, in turn, opens into the semilunar hiatus in the mid-nasal meatus (MOORE; DALLEY, 2007).

Only the maxillary and ethmoidal sinuses are present at birth. During childhood, due to the cranium and mid-facial region growth, a further development of the paranasal sinuses occurs, including the frontalis bone. Frontal sinuses formation starts at two years old, but its pneumatization occurs only around 6-7 years old, because of the migration of the ethmoidal cell to the frontalis bone (PIGNATARY et al., 2004).

Several studies have suggested that the frontal sinuses are slightly bigger in males than in females, and the presence of a metopic suture is associated with the absence of the frontal sinuses (BROWN et al., 1984; SCHULLER, 1943). Nevertheless, one of the sinuses' function is to make lighter the bone-structure complex of the skull. They function as a sounding board for the voice with modulations. The conditioning of breathing air is added to the above functions, since the frontal sinuses cool or heat the air to avoid any damage to the respiratory system. The frontal sinuses are the sites for the installation of diseases, such as rhinitis and sinusitis, which cause morphological changes in the sinuses (DIDIO LIBERATO, 1998). Ponte et al. (2005) analyzed CT scans of 60 patients with allergic rhinitis and reported changes in the paranasal sinuses of 52% of the patients. Due to their characteristic morphology, images of frontal sinuses provide great importance for the identification of non-recognizable corpses, as reported in studies by Silva-Pinto (2008) and Nambiar et al. (1999).

The mechanisms, which cause sinuses growth, are poorly understood. However, some opinions, such as nasal airflow, brain growth, the muscle traction mass and facial structures and, more recently, cellular mechanisms (adhesion and migration), have been forwarded to explain the growth (KOSSOWSKA; GASIK, 1976).

Research was carried out to verify, by skull measurements, which factors, within the limits of morphometric, modulate the development of the frontal sinuses. It is believed that the structural and morphological modification of some areas of the brain during growth and the intensity of the airflow through the pyriform aperture positively affect the formation of these spaces in the frontal bone.

Material and methods

Thirty-three skulls, mean age 68 years, of 15 females and 18 males were used. They belonged to the collection of the Laboratory of Human Anatomy of Victoria Academic Center at the Federal University of Pernambuco, Brazil. A cross-section 1.5 cm above the apex of the fronto-nasal articulation of the skulls was undertaken with an automatic saw to view the frontal sinuses. A steel caliper (150 x 0.02 mm) was employed for morphometric analysis. Skulls with traces of fractures or tumors were discarded.

Morphological measurements were arranged into four groups. Group 1 was measured before the skulls were cut transversely and included the face width, in which both extremities were taken for limits; the angle formed between the frontal and the temporal processes of the zygomatic bone; the spino-bregmatic distance, which extends from anterior nasal spine to the bregma; and finally, the glabella-lambda curvature which runs from the center of the horizontal line between the upper limits of the orbital cavities up to the lambda (Figure 1A).

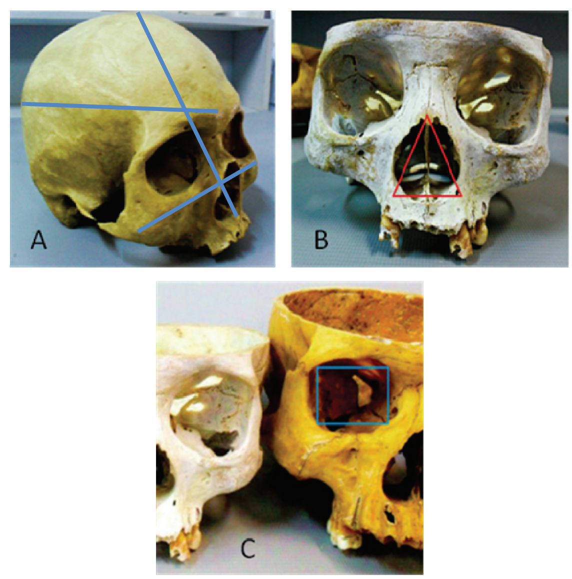

Figure 1. Maximum width of the face, the spino-bregmatic height and the glabella-lambdoid curvature are the measures that comprise the first group (A). The triangular area corresponds to maximum height and width of the pyriform aperture (B). Area of quadrangular orbit that corresponds to maximum height and width of each orbit (C).

The measurements of group 2 were represented by the maximum height and width of the pyriform aperture required to achieve the triangular area (Figure 1B). The third group is made up of the maximum height and width of each orbit, used for the calculation of its quadrangular areas (Figure 1C).

Measurements of group 4 were composed by calculating the volume of each sinus, using the mathematical formula of the volume of rectangle: width, height and maximum anteroposterior length. The latter is obtained by measuring the two cut sides of the skull (Figure 2).

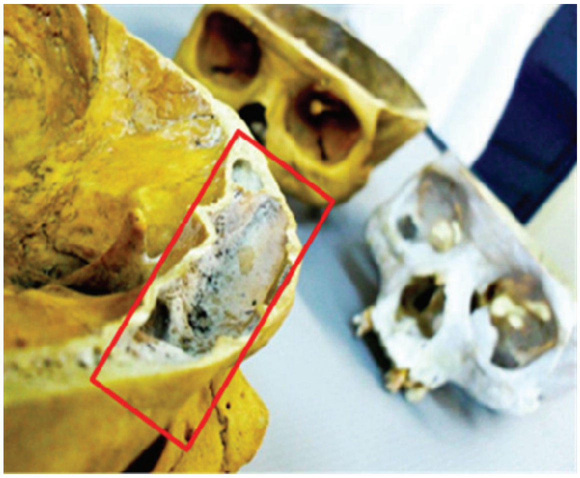

Figure 2. Volume of frontal sinus, which corresponds to width, anteroposterior length and maximum height of each sinus.

Data were digitized and analyzed by Student's t test and by Spearman and Pearson correlations (BioStat 5.0). In statistical analysis, correlation was experimented between the volume of right and left frontal sinus with the aperture pyriform area, with the area of right and left orbits, respectively, and the three skull measurements. Student's t test was carried out to compare means of the areas of the pyriform aperture between the skulls that have, at least, one of the frontal sinuses and those which have a complete agenesis.

Results

Analysis showed that 18.2% (n = 6) of the 33 skulls showed complete agenesis of the frontal sinus; 9.1% (n = 3) had unilateral agenesis and 72.8% (n = 24) presented the two sinuses. The central septum was present in 69.7% (n = 23) of the skulls and only 17.39% of the central septum were incomplete. Moreover, 57.6% (n = 19) of the skulls contained subseptum inside the chambers, ranging between 1 and 4, and seemed to be remnants of the bone structure while the paranasal front sinuses were growing.

There was significant correlation between the volume of the right frontal sinuses and the pyriform aperture area, with coefficient correlation as rs = 0.435 (p = 0.011). There was no significant correlation of the area with the left frontal sinuses; the same occurred with groups 3 and 4. There was no significant correlation between the volume of the frontal sinuses and the face's maximum width of the face in tests on groups 1 and 4. However, there was a significant correlation between the volume of the left frontal cavities and the glabella-lambda curvature; similarly, with the spino-bregmatic height. Correlation coefficients and p were equal to rs = 0.433 (p = 0.012) and rs = 0.450 (p = 0.009), respectively.

Student's t test was carried out to investigate from another angle the relationship between the sinuses and the pyriform aperture area. Individuals without the frontal sinuses had a mean pyriform aperture area equivalent to 3.841 cm^2, whereas those with one or both frontal sinuses had mean area of 4.419 cm^2, with p = 0.007.

Discussion

Results show that there is a relationship between the dimensions of the pyriform aperture and the growth of frontal sinuses, even though this may not be the determining factor. However, it is evident that these dimensions affect positively the growth of sinuses. Few studies are extant that investigate the true influences that trigger the development of paranasal sinuses and even less that of frontal sinuses.

Guimarães et al. (2007) compared the dimensions of the maxillary sinuses by CT scan in seven patients with unilateral choanal atresia. Six of the seven patients showed symmetrical sinuses. Although these results agree with those in current study, the use of such a small sample may impair results. There is frequently an association of congenital choanal atresia with facial, ocular and central nervous system malformations that may affect the development of the sinuses (DINER et al., 1986). Shin and Heo (2005) demonstrated the presence of complications and anatomical and histological alterations of the sinus mucosa due to the surgical closure of the nasal cavity.

Ponte et al. (2005) describe a study that shows the importance of the intensity of respiratory airflow. The authors evaluated computerized tomographies of patients with a history of rhinitis history, a disease involving nasal obstruction and itching which hinders or impairs normal breathing. Tomographic alterations were reported involving the paranasal sinus of 31 (52%) of the 60 patients under analysis.

A very important point in this research is the interrelationship between the spino-bregmatic height, the glabella-lambdoid curvature and the formation of the frontal sinuses. One hypothesis suggests that constant bone reorganization during skull growth in childhood and puberty boosts the expansion of these cavities. Nevertheless, one cannot discard the idea that the very development of the sinuses causes changes in the skull's configuration.

Conclusion

The dimensions of the pyriform aperture and consequently the degree of nasal cavity aeration have a relevant role in the development of the frontal sinuses. The connection between the development of the orbital cavity and sinuses has not yet been proved. However, other factors, such as the glabella-lambdoid curvature and the spino-bregmatic height seem to participate positively in the formation. Typically asymmetrical and irregularly shaped with numerous incomplete septae, the frontal sinuses are constructed by a complex anatomical architecture. In fact, the frontal sinuses have such a complex and variable anatomy that they have been used for the forensic identification of corpses of unknown people.

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