

Prevalence of agenesis of frontal sinus in human skulls with metopism

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ABSTRACT

Background: The frontal bone is an anatomical structure of the skull separated by the metopic suture in the childhood. The scientific literature indicates that metopic suture consolidates with closure in the early stages of life. Metopism is the term used to describe a metopic suture that persists up to the adulthood. Persistent metopic suture is associated potentially with the agenesis of the frontal sinus.

AIM: To investigate the prevalence of absent frontal sinuses in dry skulls with metopism.

Materials and methods: The present study was performed after the approval of the local Committee of Ethics in Research. The sample consisted of dry skulls (n=245), aging between 17 and 50 years old, of the Forensic Medical Institute of Goiânia, Brazil. The skulls underwent anthropological exam in the search for metopism. Radiographic exam was performed in the skulls with metopism to verify the presence or absence of the frontal sinus. The radiographic assessment was performed with a Mobile DaRt Evolution device (Shimadzu, Kyoto, Japan) with protocol set in 64 kV and 16 mA).

Results: From the 245 dry skulls, 17 presented metopism. The length of the metopic suture in the skulls, considering the distances between nasio and bregma craniometric landmarks, ranged between 114 mm and 137 mm. Radiographic exams were performed on 16 skulls (one skull was not analysed radiographically because of extensive destruction). Only one skull (6.25%) had the frontal sinus absent. Besides the agenesis, the present study also found four (12.5%) skulls with aplasia and eight (25.0%) hyperplasia of the frontal sinus in dry skulls with metopism.

Conclusion: The present study found a low prevalence rate of the agenesis of frontal sinuses in dry skulls with metopism.

INTRODUCTION

Sutures are fibrous joints present in the skull since foetal age. They develop from the final stage of the fontanelles until the adulthood. In the adulthood most sutures tend to disappear in a process called synostosis, which consists of the replacement of fibrous tissue by bone tissue.¹

One of the exceptions for sutures closure, in terms of age, refers to the frontal bone that is even in individuals under two years age and is separated by the metopic suture (or frontal suture).² From this age group and in some later cases (up to 7 years) this suture tends to disappear.^{3, 4}

While in one hand the disappearance of the metopic suture is a natural process, in the other hand this suture may persist in the adult.. This anatomical condition is known as metopism or persistent metopic suture.^{2,5}

The frontal bone is described as pneumatic because it has a cavity in its interior called the frontal sinus.^{6,7} This cavity is not radiologically evident in the first years of life. During childhood the development of the frontal sinus is influenced by the osteoclastic activity in the region of the ethmoidal cells.^{8,9}

The development of the frontal sinus bilaterally is independent. Yet the morphology of these sinuses is distinctive for each individual.⁶ After full maturation, which occurs in adolescence or early adulthood, the contour and expansion of the frontal sinus becomes practically immutable.^{10,11}

Based on the fact that the radiographic morphology of the frontal sinus is highly distinctive, it becomes very useful for human identification in complex cases, such as those involving carbonized and putrefied bodies, as well skeletal remains.¹²

Moreover, studies point to persistent metopic suture as a factor that could interfere in the development of the frontal sinus uni- or bilaterally, leaving it atrophic or absent.^{5,13,14} Thus, the relevance of investigating the prevalence of the agenesis of frontal sinus within subjects with metopic suture relies on potential application for human identification in Forensic Odontology. More specifically, the agenesis of frontal sinuses represents a distinctive aspect to be considered when detected post-mortem. This finding could contribute significantly for human identifications if tracked back in ante-mortem data.

The aim of this study was to investigate the prevalence of absent frontal sinuses in dry human skulls with metopism.

MATERIALS AND METHODS

This study was approved by the Committee of Ethics in Research from the Federal University of Goiás (CAAE: 55409816.9.0000.5083).

At first, all the skeleton filed at the Forensic Medical Institute of Goiânia until the end of July 2016 were examined to visually identify the presence of the persistent metopic suture in adult skulls. Incomplete skeletons in which the skulls were absent or fragmented were excluded from the sample and the skulls of children under 5

years old. Skulls with the region of the frontal bone adjacent to the ceiling of the orbits fragmented, making impossible the accomplishment of radiographic images, were also excluded from the sample.

Once the metopism was identified, the anthropological examination of the skeleton was performed by means of visual examination, which allowed the assessment of sex. This procedure was performed following the standards of Buikstra and Ubelarker (1994)¹⁵ considering four qualitative (morphological) sexual parameters in the skull, one in the mandible and one in the pelvic bones. The length of the metopic suture was also assessed, as well as the cause of death. In this step all the skulls were photographed (Figure 1) together with their respective mandibles. The age of the skeletal remains was assessed following the recommendations of Mckern and Stewart (1957)¹⁶ and Watanabe and Terazawa (2006)¹⁷, which consider the progressive alterations in human bones adulthood, such as the development of osteophytes.

Within the research sample, the skulls that presented metopic suture, intact frontal bone and with the possibility of radiographic analysis, were submitted to post-anterior skull radiography. This radiographic examination was performed the MobileDaRt Evolution device (Shimadzu, Kyoto, Japan), having exposure of 64 kV and 16 mA.

After the skull radiographic acquisition, the images were interpreted based on the presence or absence of the frontal sinus, as well as its size. Adobe Photoshop CS4® software was used to visualize and evaluate frontal sinus characteristics.

As a criterion to determine the frontal sinus size in the individuals of the sample, the study of Ribeiro (2000)¹⁸ was used as reference. In the study, the author reported a method of measuring the frontal sinus on radiographs, using measures of maximum height and maximum width of the cavity examined. If a skull does not have frontal sinus, only the distance between the projection of the lines passing through the median edges of the orbital cavities is measured (X).

To aid in the determination of frontal sinus size, the study described by Guerram et al. (2014)¹⁹ was also used. The study applied a classification method to determine differences in frontal sinus development patterns in individuals with and without metopism from radiographs. Using two perpendicular lines (one line on the supraorbital



Fig.1: Skulls from the Forensic Medical Institute – Goiânia, with persistent metopic suture (n=17)

margin, the other drawn in the middle of the orbital cavity), Guerram et al. (2014)¹⁹ classified frontal sinus size into four categories: (1) aplasia: absence of the frontal sinus; (2) hypoplasia: frontal sinus limited to the supraorbital line area; (3) medium size: frontal sinus limited to the medial area of a line drawn in the middle of the orbital cavity; and (4) hyperplasia: frontal sinus that extends in the lateral area to the line drawn in the middle of the orbital cavity.

The data obtained from the examination of the skull radiographs (frontal sinus presence or not)

and the anthropological examination (sex, estimated age, presence of the metopic suture and frontal sinus size) were tabulated in Microsoft Office EXCEL 2016 (Microsoft, USA). The SPSS (Statistical Package for Social Sciences, USA) version 21 was used for statistical analysis.

RESULTS

In a total of 266 skeletons examined at the Forensic Medical Institute of Goiânia, 245 had a skull. Of the skulls evaluated, 17 presented the persistent metopic suture (6.94%). Among these

Fig.2: Photographs of skulls with metopism and their respective radiograph.

(A) Skull with frontal sinus (B) Skull with absent frontal sinus.

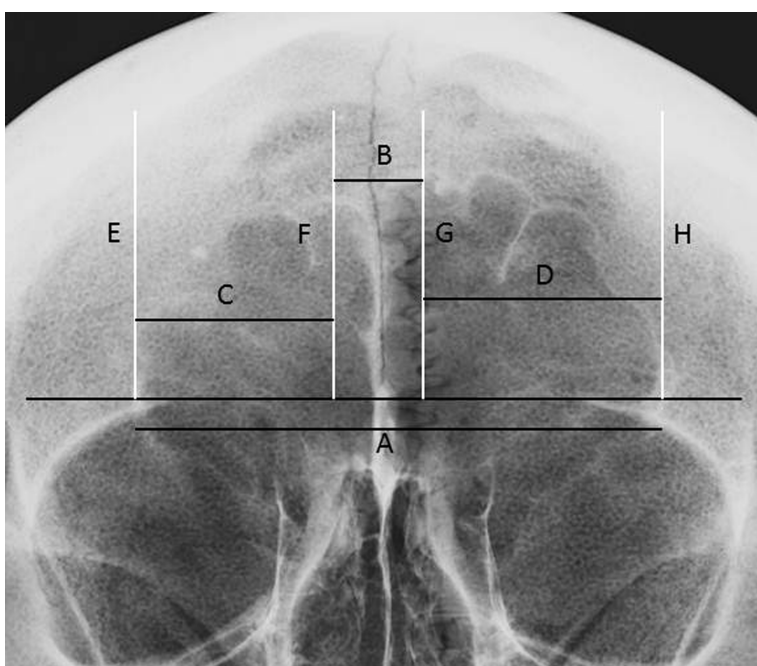


Fig.3: Parameters of Ribeiro (2000)¹⁸ to analyse the frontal sinus: a baseline is drawn horizontally along the upper limit of both orbital cavities. Four lines are then drawn perpendicular to the baseline. One line E delineates the maximum lateral limit of the right frontal sinus. Another line F passes through the highest point of the right frontal sinus. The line G is drawn through the highest point of the left frontal sinus and the line H defines the most lateral limit of the left frontal sinus. Measurement A is the maximum width of the frontal sinus. Measurement B is the distance between F and G lines. Measurements C and D are the distance between E to F lines and G to H lines, respectively.

skulls, with confirmation of the condition of metopism, a skull was excluded from the sample for evidencing an extensive fracture. From the 16 skulls that composed the radiographic sample with metopism, 6.25% presented complete absence of the frontal sinus.

The length of the metopic suture in the skulls, considering the distances between the nasal and bregma craniometric points, ranged from 114 mm to 137 mm. The estimated age varied between are located below the baseline they are negative (N); and when they are situated in the baseline, these points are classified as null (o). From the studied radiographs (n = 14) ten presented type P; one type N with P; one type N with o; one type P with N and o; and one skull revealed an absent frontal sinus (X = 1.36 cm).

Table 1 also describes data on sexual dimorphism. Three skulls were not included because they presented a fracture in calvaria. From the parameters chosen for analysis, using the skull and mandible, six (35.3%) of the cases indicated female gender, six (35.3%) suggested male gender and two (11.8%) were indeterminate. In relation to pelvis analysis for sexual dimorphism, it indicates one (5.8%) female, nine (53%) male and seven (41.2%) undetermined. The concordance between examiners considering sexual dimorphism ranged between 0.71-1.0, which suggest an almost perfect concordance (Table 2).

Table 3 shows differences in frontal sinus development patterns in the individuals of the sample who have metopism, using the same classification method that Guerram et al. (2014)¹⁹ applied in their study. In addition to agenesis, the present study also found four (12.5%) skulls with aplasia and eight (25.0%) with frontal sinus hyperplasia.

DISCUSSION

The cranial sutures influence the development of the entire skull, act on the modelling of the head growing and also during childbirth. Premature fusions of these sutures may be responsible for several conflicts between the growth of the skull and the encephalus.¹ However, there is still no consensus on the correlation between frontal sinus development and late closure of the metopic suture. From the forensic scope, metopism should be considered an important tool for human identification. While in one hand the frontal sinus itself has a distinctive morphology, in the other hand the absence of

subadult individuals, adults and elderly according to Table 1. It was observed in the radiographic examinations that the frontal sinus was present in 15 cases and agenesis was present in only one skull. Figure 2 illustrates these two conditions found.

According to the classification described by Ribeiro (2000)¹⁸, when the points delineated in lines E, F, G and H are above the baseline, they are classified as positive (P) (Figure 3); when they frontal sinuses in adult skulls is uncommon and could be considered a distinctive identifier even more valuable if tracked back in ante-mortem data. Investigating the interrelationship between metopism and agenesis of frontal sinuses could contribute significantly in the routine of medicolegal institutes.

Persistent metastatic suture is an anatomical variation which has great clinical relevance since it can be confused with traumatic skull fractures, and can also be an important characteristic in human identification. This suture can be easily evidenced in anthropological analyses for forensic purposes, as well as in conventional radiographs when the calvaria is not exposed. An important feature that differs the persistent metopic suture from a fracture is its sclerotic borders seen on skull radiographs.^{13, 20} Errors in this diagnosis can lead to misguided therapies and unnecessary interventions.²¹

Metopism occurs with a relatively low frequency. Berry and Berry (1967)²² showed a worldwide incidence between 0-7.4% in individuals of different ethnic groups. Several countries show different results, and in the Brazilian population there are discussions about incidence. In studies at Brazil, Del Sol et al. (1989)²³ evaluated 400 skulls, showing an incidence of metopism of 2.75% (2.96% in women and 2.64% in men). Castilho et al. (2006)²⁴, in an evaluation of 71 skulls, reported an incidence of 7.04% (14.28% for women and 2.32% for men). Da Silva et al. (2013)²⁵ evaluated 134 skulls, of which 13 presented persistent metopic suture (61.5% were male, and 38.5% female), with 4.48% with complete persistent metopic suture (without sex predominance) and 5.22% with incomplete persistent metopic suture (mild predominance among men). In this present study it is noticed that the results differ, observing a prevalence of 6.25%.

In view of these disagreements and considering that the four studies analysed Brazilian skulls, it

Table 1 - Estimated age determined by anthropological evaluation and skulls metopic suture length, size and classification of the frontal sinus according to Ribeiro (2000)¹⁸ and sexual dimorphism evaluation in the sample (cranium and pelvic analysis) (n=17)

SKULL NUMBER	ESTIMATED AGE (YEARS)	MS MEASURE (MM)	GENDER ACCORDING TO SKULL ANALYSIS	GENDER ACCORDING TO PELVIS ANALYSIS	A(CM)	B(CM)	C(CM)	D(CM)	TYPE
1	30-40	#	Impaired	Male	-	-	-	-	-
2	30-40	122	Male	Male	3,55	1	1,73	0,82	P
3	30-50	122	Female	Absent	3,49	1,61	1,19	0,69	P
4	30-40	#	Impaired	Male	-	-	-	-	-
5	30-40	#	Impaired	Male	-	-	-	-	-
6	> 50	134	Male	Fractured	4,04	1,04	1,36	1,64	P
7	30-40	137	Male	Male	3,4	1,04	1,09	1,27	P
8	> 40	125	Undefined	Absent	3,73	1,64	1	1,09	P
9	20-30	130	Female	Undefined	4	1,23	1,45	1,32	P
10	30-40	126	Female	Female	1,36	0	0,45	1	P,0
11	30-40	128	Female	Male	2,54	1,45	0,77	0,32	P,0
12	30-40	131	Male	Male	4,09	1,27	0,82	2	P
13	17-23	130	Female	Male	1,31	0	0,77	0,54	P,N,0
14	17-30	114	Undefined	Absent	-	-	-	-	X=1,36
15	20-30	131	Female	Absent	2,72	1,27	0,45	1	P
16	> 50	120	Male	Absent	2,64	0,82	0,91	0,91	P
17	> 50	121	Male	Male	4,17	1,54	1,45	1,18	P

P = positive; N = negative; 0 = null; X = distance between the orbits; A = the maximum width of the frontal sinus; B = distance between F and G lines; C = distance between E to F lines; D = distance between G to H lines.

Table 2: Intra and inter-examiner kappa values in the study of sexual dimorphism through the skull and mandible, according to Buikstra & Ubelaker (1994).¹⁵

TYPE OF COMPARISON	KAPPA VALUE	AGREEMENT
E1 D1 X E1 D2	1	Almost perfect
E2 D1 X E2 D2	0,81	Almost perfect
E1 D1 X E2 D1	0,80	Almost perfect
E1 D2 X E2 D2	0,71	Substantial

E = examiner; D = day.

Table 3: Frontal sinus classification according to its size in the skull that presented persistent metopic suture (n=28)

SINUS DEVELOPMENT	APLASIA (L)	HYPOPLASIA (L)	MIDIUM (L)	HYPERPLASIA (L)	Total
APLASIA (R)	1	0	2	0	3
HYPOPLASIA (R)	0	0	0	0	0
MIDIUM (R)	0	0	5	3	8
HYPERPLASIA (R)	0	0	1	2	3
Total	1	0	8	5	28

is believed that these data can be explained by the differences in the sample size, and also by the population difference that exists between the geographic regions of Brazil. In their study, Del Sol et al. (1989)²³ obtained the skulls of the south-eastern region of Brazil, while in the research developed by Castilho et al. (2006)²⁴ the skulls were from southern Brazil, and Da Silva et al. (2013)²⁵ searched for skulls in north-eastern Brazil. In the present study, skulls from the central-western region of Brazil were evaluated.

Considering the length of the complete metopic suture (present between the bregma and the nasal points), the present study showed an average length of 126.9 mm, which is slightly lower than that found by Castilho et al. (2006)²⁴, who described an average of 129.2 mm.

Some authors have reported that the presence of persistent metopic suture influences frontal sinus development.^{5, 13, 14} In this study, the classic affirmation of this possible relationship was not confirmed.

Regarding frontal sinus size, it usually presents bilaterally, asymmetric, and has a median septum splitting the right and left sides.²⁵ This morphology remains practically unchanged during adulthood, although some factors can change this structure, either through hyperpneumatization from sports activities, diseases, infections, tumours or traumas, and other factors.¹⁸

Bilgin et al. (2013)²⁶ in a study evaluating persistent metopic suture and frontal sinus development, analysed 631 computed tomography and MRI images of skulls. The presence of

atrophied frontal sinus was confirmed in cases (22.7%), 61 cases revealed persistent metopic suture (9.7%), and 15 (2.4%) had persistent metopic suture associated with the atrophied frontal sinus. Of these 15 cases, six were related to bilateral frontal sinus atrophy. This study did not present significant results in the relationship between dimorphism and frontal sinus atrophies with the presence of the persistent metopic suture.

The present study shows that 6.25% of the skulls with metopism present complete absence of the frontal sinus. Guerram et al. (2014)¹⁹ studied the frontal sinuses of 143 dry skulls, dividing them into two groups: 63 with metopism and 80 without metopism. Frontal sinuses with hypoplasia are much more frequent in skulls with the presence of persistent metopic suture (50.8% vs. 9.4%). The frontal sinus aplasia was slightly superior in skulls with metopism (7.1 vs 2.5%). The medium size was the most predominant condition in skulls without metopic suture (76.2 vs 40.5%), followed by sinus hyperplasia (11.9 vs 1.6%). Differently from these results, the present study observed that the majority of skulls with persistent metopic suture have the medium pattern (57.14%), while 12.50% are frontal sinuses with aplasia.

CONCLUSION

The present study found a low prevalence of frontal sinus agenesis in dry skulls with metopism, not evidencing the relation of the presence of this condition with the absence of frontal sinus development.

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