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A persistent Metopic Suture – Incidence and Influence on the Frontal Sinus Development (Preliminary Data)

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The relation between *metopism* and underdevelopment of the frontal sinus is controversial. This study aimed to evaluate the incidence of the metopic suture as well as to assess its influence on the frontal sinus development. The frequency of the metopic suture was investigated in a series of 1373 dry skulls from contemporary adult males. The frontal sinus development was examined into two series: a control one (n=42), and a series with preserved metopic suture (n=40). The visualization was performed via digital radiography. The statistical significance of the differences between both series was assessed using chi-square test.

The metopic suture was found in 6.85% (94 out of 1373 skulls). The incidences of uni- and bilateral aplasia of the frontal sinus were more frequent in the metopic suture series compared to the control one. The cases of uni- and bilateral hypoplasia were commensurable in both series. A frontal sinus hyperplasia was observed only in the control. The differences between both series were significant at $p < 0.01$. The frontal sinus underdevelopment in the metopic suture series was exclusively expressed on the right side. Generally, the metopic suture seems to exert a repressive influence on the frontal sinus development. Thus, the metopic suture is not a certain indicator, but is a prerequisite for an underdeveloped frontal sinus.

Key words: metopic suture; frontal sinus; dry skulls.

Introduction

The metopic suture (MS) is located between the halves of the fetal frontal bone. It is a dentate suture [2] considered to be an anterior extension of the sagittal suture [31]. The MS is the first one to close physiologically, since the fusion usually takes place during the first or second year, but the completion can last until the fourth year of age [27], as the MS can be patent to the seventh year [31]. Sometimes the MS persists in adults as the frontal bone is composed of two symmetrical halves joined in the sagittal midline and this condition is known as *metopism* [27].

There are different hypotheses focused on the reasons for non-fusion of the frontal bone. The persistent MS has not been established to be related either to the skull shape

or the cranial capacity but has been positively correlated with an increase in the frontal curvature [27]. A familial study implies that metopism is under genetic control [34]. The presumptive factors for *metopism* include an abnormal growth of the cranial bones, hydrocephalus, growth retardation, heredity and heredospecific factors, sexual influence, atavism, stenocrotaphia, plagiocephaly, scaphocephaly, mechanical causes, and hormonal dysfunction [11]. The preserved MS was found to range from 0.8% up to 15% in different population groups [1, 2, 4, 6, 8, 9, 11, 13, 17, 22, 23, 25, 33, 37]. The MS can be easily misdiagnosed as vertical traumatic skull fractures extending in the mid-line in head injury patients or even for the sagittal suture on posteroanterior roentgenograms in the clinical practice [5].

It is supposed that the persistent MS could be a prerequisite for an underdevelopment of the frontal sinus [3, 26, 33], despite the fact that the frontal bones and MS appear during early fetal life, while the pneumatization of the frontal sinus occurs after the fifth or sixth postnatal year and reaches the full size after puberty [7]. This assumption is based on the fact that the development of the frontal sinus occurs together with the growth of the frontal bone, most probably with a feedback regulating mechanism. Thus, if the frontal bones do not fuse, the MS persists and the pneumatization of the frontal sinuses may be retarded or suppressed, or they may fail to develop altogether [3, 33]. However, other studies do not show a significant association between *metopism* and aplasia of the frontal sinus [7]. In such cases, the frontal sinuses develop separately on either side of the suture and this entity can be used to differentiate a persistent MS from a fracture of the frontal bone [10]. The frontal sinus is of great importance in the forensic medicine for identification of unknown human remains [7]. In this study, we aimed to evaluate the frequency of the MS among contemporary adult males from Bulgaria as well as to assess its influence on the frontal sinus development.

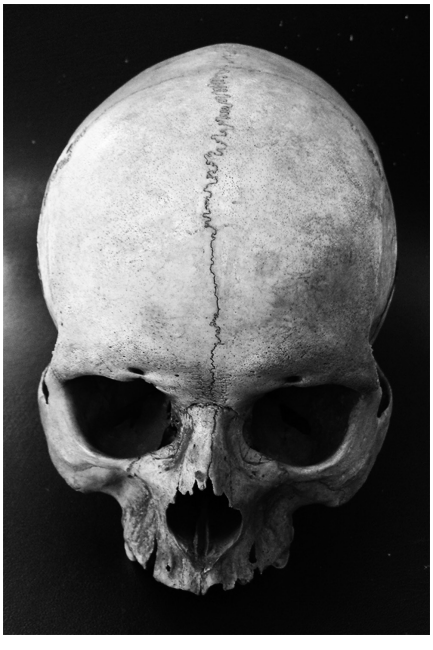

Fig. 1. Skull with entirely preserved metopic suture

Materials and Methods

The frequency of the persistent MS was investigated in a total of 1373 dry skulls of contemporary adult males. The skulls belonged to soldiers who served and died in the wars at the beginning of the 20th century: the First Balkan War, the Second Balkan War and the First World War. Their bone remains were preserved in the Military Mausoleum with Ossuary at the National Museum of Military History (Bulgaria).

The persistence of the MS was established by macroscopic inspection of the frontal bone. Only skulls with a completely preserved MS (**Fig. 1**) were accounted, i.e. the skulls with continuous suture extending from *nasion* to *bregma*.

The frontal sinus development was investigated in sample of 82 skulls grouped into two series: a control one – consisted of 42 skulls without traces from a MS, and a second series – of 40 skulls with an entirely preserved MS.

The frontal sinus was visualized through the digital radiography performed on a Nikon

XT H 225 system. The settings varied dependent on the specimens: voltage 95-126 kV, 80-100 μA tube current, exposure time of 1000 ms and 32 frames averaged. The skulls were oriented and radiographed in the occipitofrontal projection (Caldwell's view).

The development of the frontal sinus was observed bilaterally and was assessed as hyperplasia, medium, hypoplasia and aplasia according to the classification of Guerram et al. (2014) (**Fig. 2**). The facial reference lines were used after Schmittbuhl and Le Minor [28] and Schmittbuhl et al. [29]:

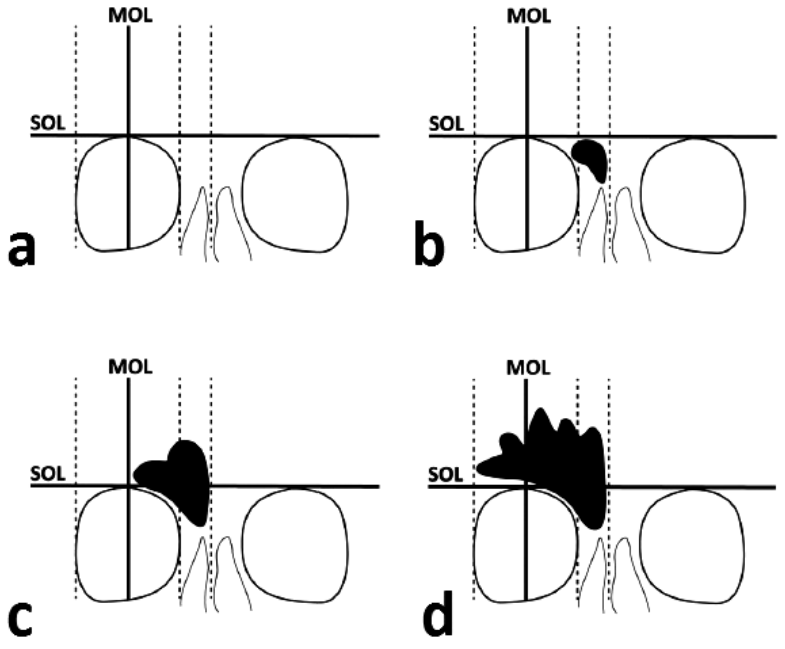

Fig. 2. Morphological quantification of the frontal sinus size after Guerram et al. (2014): a) aplasia; b) hypoplasia; c) medium; d) hyperplasia. Abbreviations: SOL – supraorbital line; MOL – midorbital line; Dotlines – midsagittal line; medial orbital line (vertical line passing through the most medial orbital point); lateral orbital line (vertical line passing through the most lateral orbital point)

1. Supraorbital line (SOL): horizontal line tangent to the superior margin of both orbits;
2. Midorbital line (MOL): vertical line, drawn for each orbit, parallel to the midsagittal line, and passing through the middle of the orbital breadth defined between the lateral orbital line (vertical line passing through the most lateral orbital point) and the medial orbital line (vertical line passing through the most medial orbital point).

The statistical significance of the differences between both series was assessed using chi-square test (χ^2).

Results

The overall incidence of the entirely preserved MS was 6.85% (94 out of 1373 skulls). The incidences of the uni- and bilateral aplasia of the frontal sinus were more frequent in the series with a persistent metopic suture (27.5%) compared to the control one

(4.8%) (**Table 1**). The cases of uni- and bilateral hypoplasia were commensurable in both series (22.5% MS; 28.6% control). Hyperplasia of the frontal sinus was observed only in the control series (11.9%). The differences between both series were statistically significant at $p < 0.01$. The frontal sinus underdevelopment in the MS series was exclusively expressed on the right side. Moreover, the aplasia was in a combination with a hypoplastic left sinus in 5 cases and with a developed left sinus in 3 cases (**Table 2**). In the control series, only 2 cases of aplasia were found as both were bilateral (**Table 3**). Bilateral hypoplasia of the frontal sinus was observed in 4 cases from the MS series and in 7 cases from the control one. Right-sided hypoplasia was found in 4 cases from the MS series and in 3 cases from the control one. Left-sided hypoplasia was observed in only 1 metopic and in 2 non-metopic skulls.

Table 1. Relation between metopic suture and development of the frontal sinus

Study	Series	Σn	Aplasia			
			bilateral		unilateral	
			n	%	n	%
Welcker [36]	MS (German)	20	4	20	5	25
Rochlih and Rubaschewa, [24]	MS Control Control (Russian)	110 80 100	31 6 7	28.2 7.5 7	18 9 4	16.4 11.2 4
Monteiro et al. [21]	MS (Portuguese)	80	6	7.5	2	2.5
Torgersen, [33]	MS–roentgenograms Non–metopic	62 400	15 20	24.2 5	– –	– –
Marciniak and Nizankowski, [19]	MS– roentgenograms MS–museum material	252 26	20 3	8 14	18 2	7.1 10.5
Baaten et al. [4]	MS (Lebanese)	8	7	87.5	0	0
Bilgin et al., [7]	MS Control	61 570	6 60	40 46.9	9 68	60 53.1
Guerram et al. [14]	MS Control (Upper Rhine)	63 80	3 1	4.8 1.25	3 2	4.8 2.5
Present study	MS (Bulgarians) Control (Bulgarians)	40 42	3 2	7.5 4.8	8 0	20 0

Table 2. Comparison of the development of the frontal sinus in our MS series with the data reported by Guerram et al. (2014)

Frontal sinus size – MS	Aplasia L		Hypoplasia L		Medium L		Hyperplasia L		Total	
Aplasia R	3	3*	5	2*	3	0*	0	0*	11	2*
Hypoplasia R	0	1*	4	29*	4	2*	0	0*	8	8*
Medium R	0	0*	1	1*	20	23*	0	1*	21	60*
Hyperplasia R	0	0*	0	0*	0	1*	0	0*	0	10*
Total	3	4*	10	32*	27	26*	0	1*	40	63*

* data after Guerram et al. (2014)

Table 3. Comparison of the development of the frontal sinus in our control series with the data reported by Guerram et al. (2014)

Frontal sinus size – Control	Aplasia L		Hypoplasia L		Medium L		Hyperplasia L		Total	
Aplasia R	2	1*	0	1*	0	0*	0	0*	2	2*
Hypoplasia R	0	1*	7	5*	3	2*	0	0*	10	8*
Medium R	0	0*	2	1*	23	56*	0	3*	25	60*
Hyperplasia R	0	0*	0	0*	0	4*	5	6*	5	10*
Total	2	2*	9	7*	26	62*	5	9*	42	80*

* data after Guerram et al. (2014)

Discussion

The observed MS incidence is in agreement with those reported for the Europeans [8, 9, 25]. In a previous study of the MS among medieval series from Bulgaria was found that the suture was more frequently observed in the female series (10.6%, 16 out of 159 skulls) compared to the male one (8.18%, 13 out of 159 skulls), but the differences were not statistically significant [23]. A comparison between the contemporary (6.85%) and the medieval (8.18%) male series showed a slightly lower frequency of the MS in the contemporary one.

Aplasia of the frontal sinus is a relatively rare but not uncommon finding. Complete agenesis of the frontal sinus occurs in 5-15% of adults and the percentage may vary in different geographic groups [16]. According to Martin [20], a congenital absence of the frontal sinuses was found in about 7% of Europeans and 30% of Australians. In our control series, aplasia of the frontal sinus was observed in 4.8%.

The relationship between the MS and a congenital absence of the frontal sinuses is contraversial. Rochlin and Rubaschewa [24] have observed a higher incidence of uni- and bilateral congenital aplasia of the frontal sinus in a MS series compared to two control ones. Torgersen [33] has also found aplasia of the frontal sinus to be more frequent in the metopic skulls. Furthermore, when the sinuses are present in metopic skulls, they tend to be reduced [32]. However, Marciniak and Nazankowski [19] and Bilgin et al. [7] have not found any strong association between both MS and frontal sinus agenesis. Baaten et al. [4] have reported an absence of the frontal sinus in 7 from 8 skulls with a MS. Slight prevalence of the frontal sinus aplasia in a MS series was also observed by Guerram et al. [14].

The frequency of the unilateral aplasia is varying as the failure of the development of one of the frontal sinuses occurs in 1-15% of adults [12]. The unilateral aplasia has been found to be more common than the considerably rarer bilateral one [26]. However, in the studies of Rochlin and Rubaschewa [24], Marciniak and Nazankowski [19] and Bilgin et al. [7] on MS series, such a tendency could not be established. Our results showed a considerable prevalence of the frontal sinus aplasia in the MS series as the unilateral cases were more frequent (**Tables 2, 3**) and exclusively expressed on the right side (**Fig. 3**).

Guerran et al. [14] have found that both aplasia and hypoplasia of the frontal sinus were considerably more frequent in the MS skulls as the differences generally came from the higher frequency of the cases with hypoplasia. As it could be seen from our results, the overall cases of absence and underdeveloped frontal sinus were also more

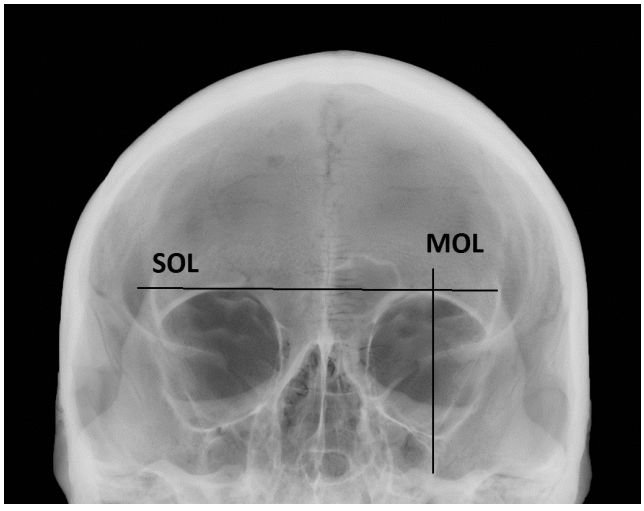

Fig. 3. Roentgenogram of the skull with a metopic suture showing right side aplasia and left side sinus of medium size. Abbreviations: SOL – supraorbital line; MOL – midorbital line

frequent in the MS compared to the control series as the prevalence was at the expense of the cases of aplasia which was entirely right-sided (**Tables 2, 3**).

The right and left lobes of the frontal sinus develop independently and often display asymmetry, which is generally attributed to a more rapid development on one side at the expense of the other [35]. Some authors have reported that the right lobe of the sinus tends to be larger than the left counterpart [15, 18, 27]. Other researchers have found a predominance of the left lobe [16, 19]. According to other studies, there have not been established any significant differences between the dimensions of both frontal lobes [32]. Our results showed clearly a tendency to left lobe dominance as in the MS series this tendency was expressed even more strongly (**Table 2**).

Conclusion

The MS frequency in the contemporary adult males from Bulgaria was comparable to those reported for the Europeans. The persistence of the MS was often related to a frontal sinus aplasia and/or hypoplasia, so it could be considered that it exerts a repressive influence. Thus, the MS is not a certain indicator but is a prerequisite for an underdeveloped frontal sinus.

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