Int. J. Morphol.,
44(4):1165-1173, 2026.

Prevalence of Metopism with Persistent Premaxillary Suture and Accessory Bones in Adult Anatolian Crania

Prevalencia de Metopismo con Sutura Premaxilar Persistente y Huesos Accesorios en Cráneos Adultos de Anatolia

Irem Aymelek[1]; Alpen Ortug[2] & Gursel Ortug[3]

AYMELEK, I.; ORTUG, A. & ORTUG, G. Prevalence of metopism with persistent premaxillary suture and accessory bones in adult Anatolian crania. *Int. J. Morphol., 44(4)*:1165-1173, 2026.

SUMMMARY: Cranial sutures show significant anatomical variation across populations and are clinically relevant in craniofacial assessment. The aim of this study was to determine the frequency of co-presence of the metopic suture and the premaxillary suture in adult dry skulls from Anatolian region, to classify metopic suture morphology (V, H, L), to evaluate its relationship with cranial index (CI), and to assess the presence of accompanying accessory bones. Among ninety seven adult Anatolian crania, a metopic suture was identified in 31 specimens (15 males, 16 females). Partial metopism was observed in 74.2 % (n = 23) and complete metopism in 25.8 % (n = 8), with no sex difference. In crania with partial metopism, the L type was most common (39.1 %, n = 9), followed by the V type (34.8 %, n = 8) and the H type (26.1 %, n = 6). A premaxillary suture was present in 22.6 % of metopic crania (n = 7), with no significant differences by sex (26.7 % in males, 18.8 % in females) and no association with cranial index. Accessory bones were detected in 54.8 % (n = 17) and were not associated with sex, metopism status, or cranial index. In conclusion, CI was not a significant predictor of premaxillary suture presence. These findings provide baseline prevalence data for metopism, persistent premaxillary suture, and accessory cranial bones in an adult Anatolian sample and may inform anatomical and clinical interpretation.

KEY WORDS: Anatomy; Craniofacial abnormalities; Cranial traits; Metopic suture; Metopism; Osteologic analysis; Premaxillary suture.

INTRODUCTION

The calvaria undergoes changes in response to brain development (Richtsmeier & Flaherty, 2013) and does not simply expand passively; rather, it produces new bone at the sutural edges of the bone fronts in response to external stimuli, including signals arising from the expanding cerebral lobes, indicating that cranial vault growth is coordinated with brain growth (Schaurich *et al*., 2024). The mechanical forces that modulate bone growth at the sutures include underlying brain growth, interactions at the dural–calvaria interface, and external factors such as compression, which can lead to bone resorption along the suture rather than suture fusion (Richtsmeier & Flaherty, 2013; Flaherty *et al*., 2016). At birth, the cranial bones are connected by membranous articulations, and over time these structures close under the influence of genetic mechanisms, forming the sutures (Beederman *et al*., 2014; Li *et al*., 2021). The human skull contains a variable number of sutures, and in some individuals, isolated sutural bones formed by additional ossification centers within the sutures (supernumerary bones), known as Wormian bones, may be present (Bellary *et al*., 2013; Özbek & Vural, 2017).

Cohen Jr. (1993) describes suture biology using two basic fusion models: midline and non-midline sutures. In midline sutures, the bony margins approach each other end to end (for example, the sagittal suture and the metopic or interfrontal suture), whereas in non-midline sutures the bones overlap as they unite. Sutures that fail to close are described as persistent, patent, or incomplete sutures (White *et al*., 2021; Sharma *et al*., 2024).

The metopic suture, located along the bregma to nasion line and joining the frontal bones, is referred to by

[1] Bahcesehir University, School of Medicine, Istanbul, Turkiye.
[2] Department of Radiology, Massachusetts General Hospital and Harvard Medical School, Boston, USA
[3] Bahcesehir University, School of Medicine, Department of Anatomy, Istanbul, Turkiye.

Received: 2026-02-16 Accepted: 2026-06-22

various terms when it remains completely or partially open in adulthood: persistent frontal suture (sutura frontalis persistens), caput cruciatum, interfrontal suture (sutura interfrontalis), frontal suture (sutura frontalis), and mediofrontal suture (sutura mediofrontalis) (Hauser, 1989; Sharma *et al*., 2024). A persistent suture in the primary palate within the maxilla is also described by different names, including persistent premaxillary suture, persistent sutura incisiva, sutura praemaxillaris, premaxillary fissure, incisive fissure, and the premaxillary maxillary suture (Lisson & Kjaer, 1997; Trevizan *et al*., 2018).

The metopic suture typically fuses in early childhood and may persist in association with facial sutures such as the premaxillary suture; therefore, the developmental trajectories of these structures are often examined together (Vinchon, 2019). Facial primordia emerge around the future oral region during the fourth week of embryonic development with contributions from the pharyngeal arches (Som & Naidich, 2014; Ansari & Bordoni, 2024). Through migration and interactions of neural crest cells, a total of seven prominences form around the stomodeum: one frontonasal, paired lateral nasal and medial nasal, paired maxillary, and paired mandibular prominences (Aldridge *et al*., 2011; Posnick, 2014). The maxillary and mandibular prominences arise from the first pharyngeal arch, whereas the frontonasal prominence develops from a midline primordium formed over the prosencephalon (Roth *et al*., 2021). The frontonasal prominence contributes to the forehead, the middle of the nose, the philtrum, and the primary palate, while the maxillary prominences contribute to the secondary palate and to the lateral parts of the face and upper lip (Tapadia *et al*., 2005). Fusion of the medial nasal prominences forms the intermaxillary segment that gives rise to the primary palate, whereas protrusion and growth of the lateral prominences contribute to formation of the secondary palate (Sperber, 2013; Posnick, 2014).

The degree of closure of the premaxillary suture can be assessed using quantitative and qualitative methods. Quantitative assessment is performed by measuring the distance from the lateral incisors to the median palatine suture (Trevizan *et al*., 2018). Classification of metopism is generally qualitative as a continuous suture extending along the bregma to nasion line, considered complete persistence, whereas sutures that do not show this configuration are considered incomplete (Ajmani *et al*., 1983; Castilho *et al*., 2006; Murlimanju *et al*., 2011). Incomplete sutures are classified as V, U, and H shaped, as well as double and linear forms (Ajmani *et al*., 1983; Castilho *et al*., 2006; Murlimanju *et al*., 2011).

The timing of complete, normal (physiological) closure of the metopic suture remains controversial, with reports ranging from fusion at birth or as early as a mean age of 3 months to as late as 8 years; while some studies suggest it typically closes before the second year of life and others propose closure begins around age 2 years, most authors place normal closure between 1 and 3 years (Manzanares *et al*., 1988; Vu *et al*., 2001; Sharma *et al*., 2024). Its prevalence varies by ancestry, sex, and cranial types (dolichocephalic, mesocephalic, brachycephalic) (Barteczko & Jacob, 2004; Erogˇlu, 2008; Wróbel, 2017). Similarly, the timing of closure of the premaxillary suture, derived from the primary palate, is not definitive; it has been suggested that closure begins in the fetal period and may continue until approximately 6 years of age (Trevizan & Consolaro, 2017; Nicol *et al*., 2020; Capote *et al*., 2023).

Cranial sutures are clinically important landmarks because normal variation in their development and persistence can be associated with craniofacial disorders and can also be misinterpreted as pathology on imaging (Sharma *et al*., 2024). Metopism may result from various factors such as hereditary factors, mechanical stress, endocrine dysfunctions and craniofacial disorders (such as Tessier syndrome or cleidocranial dysostosis) (Pacífico *et al*., 2025). It may be associated with frontal sinus hypoplasia, increased intracranial pressure, growth delay, cognitive changes, and different cranial types (dolichocephalic, mesocephalic, brachycephalic) (Ashley-Montagu, 1937; Torgersen, 1950; Linc & Fleischmann, 1969; Ajmani *et al*., 1983; Nikolova *et al*., 2022; Sharma *et al*., 2024). Metopism can also be mistaken for skull fractures on imaging (Vega *et al*., 2024), can mimic the skeletal trauma, an important medicolegal aspect (Mann & Hunt, 2019). The presence of a premaxillary suture has been associated with prognathism, deep bite, cleft lip and palate, protrusion, and congenital pyriform aperture stenosis (Barteczko & Jacob, 2004).

Therefore, co-occurrence of the metopic and premaxillary sutures should be considered not only a morphological variation but also a finding of developmental interest, given their shared embryological origin in craniofacial development. In this study, we aimed to determine the prevalence of the metopic and premaxillary sutures, describe their patterns of co-occurrence, and explore whether co-occurrence is associated with craniofacial morphological variation, including cranial type. We hypothesized that co-occurrence would show identifiable patterns across metopism types and cranial forms, providing reference data relevant to clinical anatomy, radiology, and craniofacial surgery.

MATERIAL AND METHOD

Specimen information

This study included the 31 crania with metopism identified within a larger series of 97 adult Anatolian crania that showed no evidence of prior surgical intervention, pathological change, or trauma. The study was approved by the Bahcesehir University Board of Scientific Research and Publishing Ethics and was conducted in accordance with the Declaration of Helsinki.

Measurements

Cranial sex estimation was performed by assessing commonly accepted nonmetric anthropological landmarks using standard criteria (Krogman & Iscan, 1986; Williams & Rogers, 2006). Thirteen morphological traits were evaluated for sex estimation, reflecting overall cranial form. These included overall size and structure, the supraorbital region, mastoid process, occipital region, frontal and parietal eminences, orbital morphology, forehead contour, zygomatic bone morphology, the extent and articulation of the malar region at the zygomaticomaxillary junction, and palatal shape (Ortug & Uzel, 2019; Elbizim *et al*., 2022). All observations were recorded on a sex determination form, and the results were documented and archived.

After first determining the presence of a metopic suture in each cranium and, when present, whether it was complete or partial, incomplete sutures were classified as V type, H type, or L (linear) type according to existing literature (Castilho *et al*., 2006; Knapp & George, 2023) (Fig. 1).

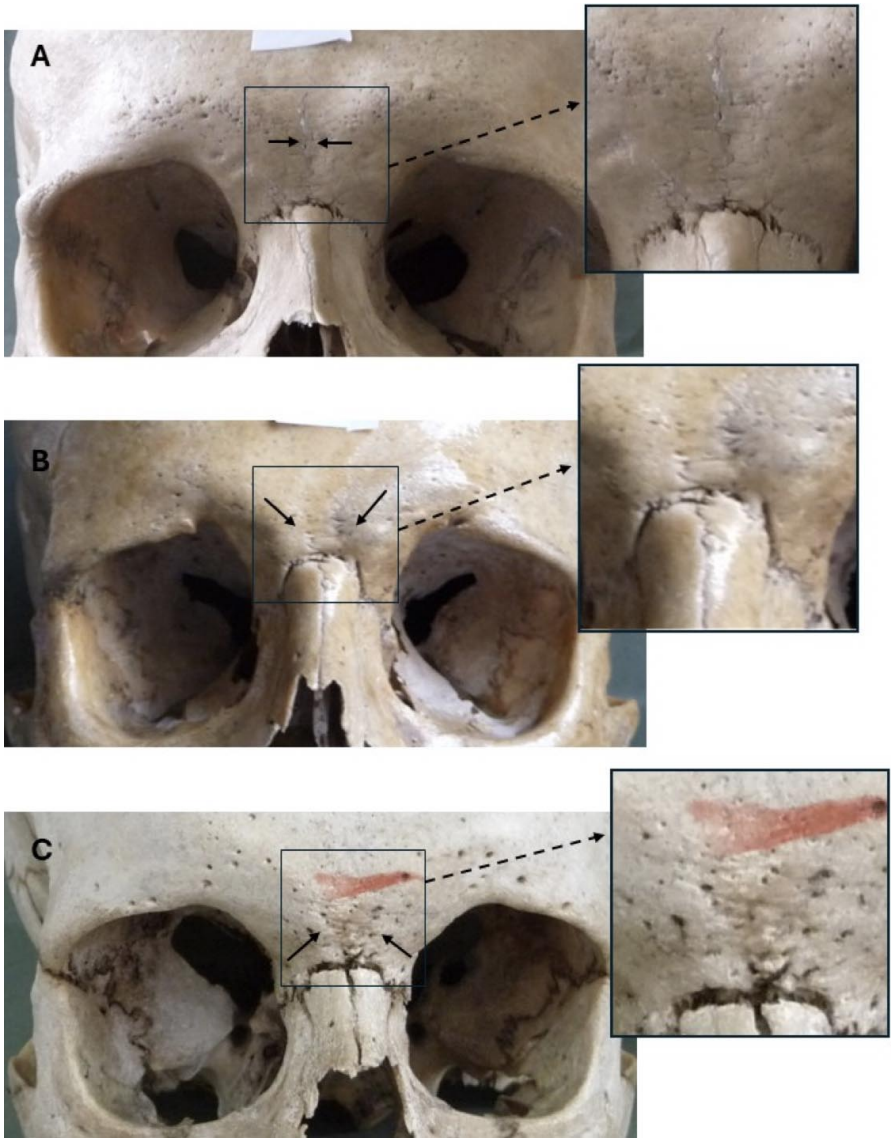


Fig. 1. Types of incomplete metopic suture. Representative examples of incomplete metopic suture patterns observed on adult skulls.

A) L type (linear): a short, linear remnant of the metopic suture confined to the lower frontal bone.

B) H type: bilateral linear remnants extending laterally from the midline, giving an H like appearance.

C) V type: paired oblique remnants converging inferiorly toward the nasion, forming a V shaped configuration.

Black arrows indicate the margins of the incomplete metopic suture. Boxed areas in the upper right of each image highlight the region of interest, with corresponding magnified views shown on the right.

In crania with a metopic suture, we assessed the co-presence of a persistent premaxillary suture, sex related variation, and the frequency of accompanying accessory bones (Fig. 2). Cranial index was then calculated to evaluate differences in cranial morphology. The findings were analyzed according to sex and sutural distribution.

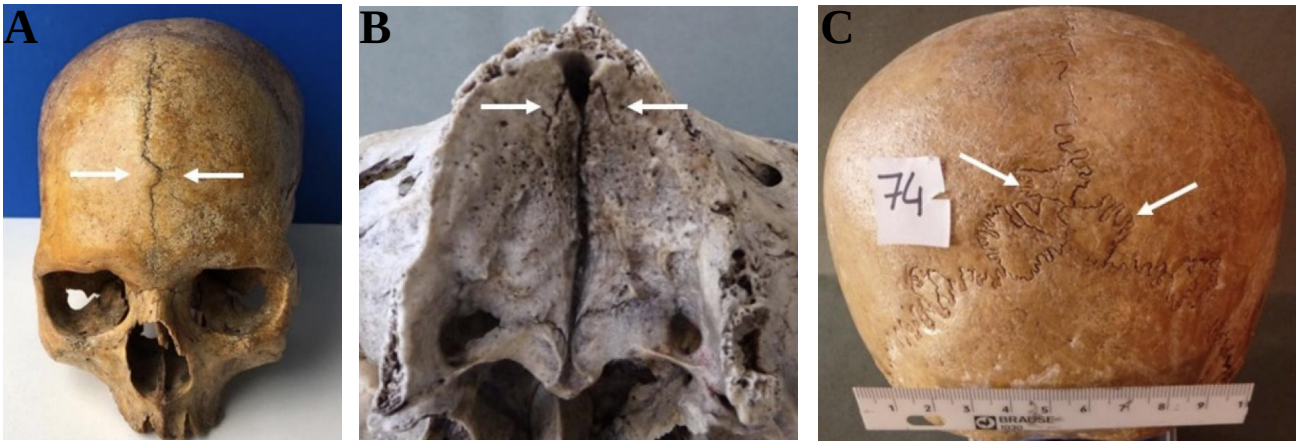


Fig. 2. Suture variations: A) metopic suture; B) premaxillary suture; C) accessory bone.

For cranial index (CI) calculations, maximum cranial breadth (between the euryon points) and maximum cranial length (between opisthocranion and glabella) were measured (Martin, 1928). Measurements were obtained using a 150 mm digital caliper (Altas 905) and an anthropometric caliper (Ruiz-Correa *et al*., 2006; Ay *et al*., 2021). The cranial index was calculated using the following formula:

$$CI = \frac{\text{Cranial Breadth}}{\text{Cranial Length}} \times 100$$

Crania were classified as dolichocephalic (CI < 75), mesocephalic (CI = 75–79.9), or brachycephalic (CI ≥ 80–84.9) (Martin, 1928).

Statistical Analysis

All statistical analyses were performed using SPSS (version 30; IBM, Chicago, IL, USA). Continuous variables were summarized as mean, standard deviation, minimum, and maximum values. Independent samples t tests were used to compare cranial breadth, cranial length, and cranial index between male and female crania. The difference in cranial index between groups with and without accessory bones was evaluated using the same method. Categorical variables were expressed as counts and percentages, and chi square tests were applied to compare frequency distributions between groups. When expected cell counts were less than five, Fisher exact test or the Fisher Freeman Halton exact chi square test was used, as appropriate. To examine the association between the presence of a premaxillary suture and cranial index, a univariable logistic regression model was fitted, and odds ratios were reported with 95 percent confidence intervals. All tests were two sided, and $p < 0.05$ was considered statistically significant.

RESULTS

Metopism, either complete or partial, was identified in 31 specimens out of 97, including 15 males and 16 females. The mean cranial breadth was 13.84 ± 0.84 cm, the mean cranial length was 17.12 ± 0.75 cm, and the mean cranial index was 81.00 ± 6.38. Cranial breadth was significantly greater in males than in females (14.24 ± 0.58 cm vs 13.58 ± 0.89 cm, p = 0.03; Table I). In contrast, cranial length and cranial index did not differ significantly between sexes (p = 0.19 and p = 0.42, respectively). Cranial type distribution also did not differ significantly between male and female crania (chi square test, p = 0.27). Descriptive statistics and cranial type distributions for the full sample are presented in Table I.

Partial metopism was observed in 74.2 % of specimens (n = 23) and complete metopism in 25.8 % (n = 8), with no sex related difference in this distribution (Fisher exact p = 0.69). Among the 23 crania with partial persistent metopic sutures, the most common morphology was the L type (39.1 %), followed by the V type (34.8 %) and the H type (26.1 %). The distribution of persistent metopic suture morphology types did not differ significantly by sex (Fisher Freeman Halton exact p = 0.51). The distributions of the premaxillary suture, persistent metopic suture, accessory bones, and metopism morphology in females, males, and the total sample are given in Table II.

Table I. General cranial characteristics and cranial types.

Variable	Male (n = 15) Mean ± SD (min-max)	Female (n = 16) Mean ± SD (min-max)	All (n = 31) Mean ± SD (min-max)	p-value
Number of crania	n = 15	n = 16	n = 31	
Cranial breadth	14.24 ± 0.58 (14 to 15)	13.58 ± 0.89 (12 to 15)	13.84 ± 0.84 (12 to 15)	**0.03**
Cranial length	17.35 ± 0.65 (16 to 19)	16.98 ± 0.79 (16 to 18)	17.12 ± 0.75 (16 to 19)	0.186
Cranial index (CI)	82.19 ± 4.30 (73 to 90)	80.25 ± 7.41 (69 to 94)	81.00 ± 6.38 (69 to 94)	0.419
Cranial type, n (%)				0.270[1]
Brachycephalic CI ≥ 80	12 (80.0 %)	10 (62.5 %)	22 (71.0 %)	
Mesocephalic CI (75 - 79.9)	2 (13.3 %)	1 (6.3 %)	3 (9.7 %)	
Dolichocephalic CI ≤ 74.9	1 (6.7 %)	5 (31.3 %)	6 (19.4 %)	

[1]The p value from the chi square test comparing cranial type distribution between male and female crania.

Table II. Non-metric variant analysis.

	Male (n = 15)	Female (n = 16)	All (n = 31)	p-value
Premaxillary suture n (%)				0.69[1]
None	11 (73.3 %)	13 (81.3 %)	24 (77.4 %)	
Present	4 (26.7 %)	3 (18.8 %)	7 (22.6 %)	
Accessory cranial bones n (%)				0.29[1]
None	5 (33.3 %)	9 (56.3 %)	14 (45.2 %)	
Present	10 (66.7 %)	7 (43.7 %)	17 (54.8 %)	
Metopic suture n (%)				0.69[1]
Complete	3 (20.0 %)	5 (31.3 %)	8 (25.8 %)	
Partial	12 (80.0 %)	11 (68.8 %)	23 (74.2 %)	
Shape of metopic suture n (%)				0.12[2]
H	5 (41.7 %)	1 (9.1 %)	6 (26.1 %)	
L	5 (41.7 %)	4 (36.4 %)	9 (39.1 %)	
V	2 (16.7 %)	6 (54.5 %)	8 (34.8 %)	

Metopic suture morphology was evaluated only in crania with partial metopism (male n = 12, female n = 11, total n = 23). In one case, the metopic suture morphology could not be determined. [1] The p value from the two sided Fisher exact test comparing the distribution of the relevant nonmetric variant between male and female crania.[2] The p value from the Fisher Freeman Halton exact chi square test comparing the distribution of metopic suture morphology categories between male and female crania.

When cranial index-based classifications were evaluated in crania with a metopic suture, most were brachycephalic (71.0 %, n = 22), followed by dolichocephalic (19.4 %, n = 6) and mesocephalic (9.7 %, n = 3). Complete metopism was most frequently observed in brachycephalic (75.0 %, n = 6) and dolichocephalic (25.0 %, n = 2) crania, whereas no complete metopism was identified in mesocephalic crania. Partial persistent metopic sutures were most common in brachycephalic crania (69.6 %, n = 16), followed by dolichocephalic (17.4 %, n = 4) and mesocephalic (13.0 %, n = 3) crania.

When partial metopic suture morphologies (V, H, L) were assessed by cranial type, the L type predominated in brachycephalic crania (H: 31.25 %, n = 5; L: 50.0 %, n = 8; V: 18.75 %, n = 3), whereas the V type was proportionally more frequent in dolichocephalic (V: 75.0 %, n = 3; L: 25.0 %, n = 1) and mesocephalic crania (V: 66.6 %, n = 2; H: 33.3 %, n = 1).

A premaxillary suture was identified in 22.6 % (n = 7) of the 31 crania with a metopic suture, with a similar distribution between males and females (Fisher exact p = 0.69). The premaxillary suture was present in 26.7 % of males (n = 4/15) and 18.8 % of females (n = 3/16), with no statistically significant sex difference ($p > 0.05$). By metopism status, the premaxillary suture accompanied 37.5 % of crania with complete metopism and 17.4 % of crania with partial metopism. By metopic suture morphology, the premaxillary suture was most frequent in the H type (60.0 %, n = 3) and was observed at equal proportions in the L (20.0 %, n = 1) and V (20.0 %, n = 1) types.

In the univariable logistic regression analysis evaluating the association between premaxillary suture presence and cranial index, overall model fit was not statistically significant ($\chi^2 = 0.30$, df = 1, p = 0.59) and model explanatory power was low (Nagelkerke $R^2 = 0.014$). Cranial index was not a significant predictor of premaxillary suture presence (odds ratio = 1.04, 95 % CI 0.90 to 1.20, p = 0.59) (Table III), indicating no significant association between cranial index and the presence of a premaxillary suture.

Descriptively, the premaxillary suture was observed in 71.4 % of brachycephalic (n = 5), 14.3 % of dolichocephalic (n = 1), and 14.3 % of mesocephalic crania (n = 1).

Table III. Logistic regression model evaluating the association between cranial index and the presence of the premaxillary suture.

Variable	OR	95 % CI	p
Cranial index	1.04	0.90–1.20	0.59

Accessory bones were identified in 54.8 % of cases (n = 17). The presence of at least one accessory bone (Wormian and/or Inca) was observed in 43.8 % of female crania (n = 7) and 66.7 % of male crania (n = 10), with no statistically significant difference between sexes (Fisher exact p = 0.29). Accessory bones were present in 62.5 % of crania with complete metopism (5/8) and in 52.2 % of crania with partial metopism (12/23). Among cases with partial metopic sutures, accessory bones were observed at similar rates across morphology types, including the V type (33.3 %, n = 4), L type (33.3 %, n = 4), and H type (25.0 %, n = 3). The mean CI was 82.19 ± 5.30 (brachycephalic) in crania without accessory bones and 80.36 ± 6.71 (brachycephalic) in crania with at least one accessory bone, and this difference was not statistically significant ($t(29) = 0.83$, $p = 0.41$).

DISCUSSION

This study aimed to determine the prevalence of metopism, the premaxillary suture, and accessory cranial bones in adult Anatolian crania, and to evaluate the relationships of these nonmetric variants with sex, cranial form (cranial index), and cranial type. Our findings provide baseline prevalence data for these structures and suggest that the associations among these variants and with cranial morphology are limited in this sample.

Prevalence and Determinants of Metopism

In our study, the incidence of metopism was 32 %. This value is close to the upper end of the 1 % to 38.17 % range reported in the literature (Agarwal *et al*., 1979; Yadav *et al*., 2010; Zdilla *et al*., 2018). In contrast, Eroglu's study of 487 crania from Ancient Anatolian populations reported a metopism prevalence of 3.3 % to 14.9 %, which is markedly lower than the rate observed in our sample (31 %) (Eroglu, 2008). Erog˘lu's dataset spans a broad population from different chronological periods and demonstrates that the frequency of the metopic suture varies across centuries. The higher prevalence in our study may, in part, reflect differences in sample size and the narrow time range of the adult crania examined. These observations suggest that metopism may be influenced not only by interpopulation genetic differences but also by environmental factors (Podstawka *et al*., 2024).

Metopism prevalence reported across populations includes 10.18 % in Chinese (Li *et al*., 2023), 8.06 % in Europeans (Zdilla *et al*., 2018), 18.04 % in Indians (Yadav *et al*., 2010), 34.97 % in Nigerians (Ajmani *et al*., 1983), and 9.7 % in Brazilians (da Silva *et al*., 2013); another study of skulls from southern Brazil reported 39 % (Castilho *et al*., 2006), and the prevalence observed in our study was higher than most of these values. This variability has primarily been attributed to genetic factors, and metopism has been suggested to occur more frequently in populations in which long lineal individuals predominate (Castilho *et al*., 2006). Given that our sample represents an Anatolian population, the relatively high prevalence may also relate to the heterogeneous genetic background of Anatolia, consistent with its geographic location and complex population history as noted by Eroglu (2008). This genetic diversity may contribute to the higher frequency observed in our series compared with some other populations.

In our study, although no statistically significant difference was found in the prevalence of metopism between sexes, the metopic suture was observed more frequently in females (n=16/31). Reports on sex related differences in metopism prevalence are similarly inconsistent across the literature. Accordingly, some studies have found a higher prevalence in males (Baaten *et al*., 2003; Skrzat *et al*., 2004; Murlimanju *et al*., 2011; van der Meulen, 2012; da Silva *et al*., 2013) whereas others reported a higher prevalence in females (Castilho *et al*., 2006; Baresa *et al*., 2024). In addition, a study comparing modern and archaeological samples from a Croatian population reported a slightly higher frequency in men across most time periods, except the modern period, yet no significant sex differences were observed; the same study noted higher overall frequencies in women in Anatolian populations, with variation across time periods and settings but again without significant differences between men and women (Baresa *et al*., 2024). The authors also interpreted their findings to suggest that secular changes across different time periods do not markedly affect the incidence of the metopic suture, and that variation in reported frequencies likely reflects population differences and limited statistical power, given the generally low prevalence of metopism (Baresa *et al*., 2024).

The relationship between the metopic suture and cranial types was also evaluated, and in our study, metopism was observed most frequently in the brachycephalic group. Silva *et al*., reported that the metopic suture was more common in dolichocephalic crania (7.46 %) (da Silva *et al*., 2013), whereas Castilho *et al*. (2006) reported findings

consistent with ours, with the highest frequency (52.2 %) observed in brachycephalic crania. This association may reflect shared developmental influences on cranial vault morphology and metopic suture persistence. Specifically, the spatial configuration of a brachycephalic skull may modify biomechanical tensions during cranial development, thereby affecting metopic suture fusion. At the same time, variability across studies may reflect population specific genetic differences and methodological heterogeneity, including differences in cranial type classification and in the criteria used to define metopism

Premaxillary suture prevalence and associations

Given that other midline craniofacial variants may share developmental pathways with the metopic suture, we next evaluated the premaxillary suture and its co-occurrence with metopism. The premaxillary suture is a structure that embryologically shares a common developmental trajectory with the metopic suture and represents a continuation of the intermaxillary segment that contributes to formation of the primary palate (Vinchon, 2019). Information regarding the timing of closure of this suture and its persistence into adulthood remains limited and variable (Trevizan & Consolaro, 2017; Nicol *et al*., 2020; Capote *et al*., 2023). In our study, the co-occurrence rate of the premaxillary and metopic sutures was 22.6 %. Although the premaxillary suture was observed more frequently in males, this difference was not statistically significant, and no clear association between sex and premaxillary suture presence was identified.

We also assessed potential associations with cranial form using cranial index comparisons and logistic regression. Neither the categorical cranial type comparisons nor models incorporating cranial index as a continuous predictor showed a significant relationship with premaxillary suture presence, and the explanatory power of the models remained low. Although these sutures are developmentally linked, persistence of one does not necessarily imply persistence of the other in adulthood. This may reflect interindividual variability in metopic suture closure timing and the continuum between delayed closure and persistent metopism described in pediatric imaging studies (Vinchon, 2019). In addition, in dry crania, macroscopic recognition of sutural remnants may be influenced by remodeling and preservation related factors, which should be considered when interpreting negative findings. Nevertheless, the small number of crania with a premaxillary suture and the wide confidence intervals limit inference, and larger series with supporting demographic or clinical data are needed to clarify co-occurrence patterns and potential associations with cranial morphology.

Accessory Bones Accompanying the Metopic Suture

We next evaluated accessory cranial bones as additional nonmetric variants observed in crania with a metopic suture. In our study, the rate of accessory bones accompanying the metopic suture was 54.8 %. Reported frequencies vary widely in the literature (8 %–91.66 %) (Bellary *et al*., 2013; Cirpan *et al*., 2016; Li *et al*., 2023; Güler *et al*., 2024), likely reflecting differences in sample collections, definitions, and inclusion criteria for accessory bones, as well as methodological variation in their detection. In our sample, accessory cranial bones accompanying the metopic suture were observed more frequently in males (66.7 %), although this difference did not reach statistical significance and cranial breadth was the only parameter showing a significant difference. The literature is similarly inconsistent regarding sex related patterns, with some studies reporting higher prevalence in males (Güler *et al*., 2024), others in females (Durge, 2016), and others finding no significant sex difference (Gümüsburun *et al*., 1997).

Cranial index, analyzed as a continuous measure, tended to be lower in crania with accessory bones in our analysis. However, when cranial type was examined categorically, accessory bones were most frequently observed in the brachycephalic group. This apparent divergence likely reflects the use of threshold based cranial type categories, where individuals near cutoff values can shift groups despite small differences in cranial index, as well as the influence of small subgroup sizes and sampling variability. In line with this, prior studies report heterogeneous findings, with some describing higher frequencies in brachycephalic crania (Gümüsburun *et al*., 1997) and others reporting higher prevalence in dolichocephalic (Kilic-Safak *et al*., 2020) or mesocephalic (Padhy *et al*., 2025) crania. Overall, our findings support a high, but variable frequency of accessory bones in metopic crania, while suggesting that any apparent sex or cranial form patterns are not robust and should be interpreted cautiously considering inconsistent evidence across studies.

Limitations

Our study has several limitations. First, the sample size is limited, and because only seven crania exhibited a premaxillary suture, the statistical power of analyses related to this variant is low; the non-significant logistic regression results and wide confidence intervals are expected consequences of this limitation. The crania examined were selected from anatomy laboratory skull collections, and because information on age, precise ancestry, and clinical characteristics of individuals is unavailable, generalization of our findings to the broader population should be made cautiously. Our measurements were restricted to linear dimensions obtained from dry crania; three dimensional or imaging-based analyses could not be

performed, and observer dependent measurement error cannot be fully excluded. In addition, classification of metopic suture morphology is partially interpretive, and some subgroups included few cases; therefore, these findings should be supported by larger series.

CONCLUSION AND FUTURE DIRECTIONS

Overall, these preliminary findings provide baseline prevalence estimates for metopism, persistent premaxillary suture, and accessory cranial bones in adult Anatolian crania, and indicate that clear associations with sex and cranial morphology were not detected in this sample using standard assessment methods. Larger, demographically characterized collections are needed to refine these prevalence estimates and better define co-occurrence patterns and developmental relationships among midline craniofacial variants.

ACKNOWLEDGMENTS. The authors thank the departments of Anatomy of Istambul University School of Dentistry and Ankara University School of Medicine for access to their cranial collections.

AYMELEK, I.; ORTUG, A. & ORTUG, G. Prevalencia de metopismo con sutura premaxilar persistente y huesos accesorios en cráneos adultos de Anatolia. *Int. J. Morphol., 44(4)*:1165-1173, 2026.

RESUMEN: Las suturas craneales presentan una variación anatómica significativa entre poblaciones y son clínicamente relevantes en la evaluación craneofacial. El objetivo de este estudio fue determinar la frecuencia de coexistencia de la sutura metópica y la sutura premaxilar en cráneos secos adultos de la región de Anatolia, clasificar la morfología de la sutura metópica (V, H, L), evaluar su relación con el índice craneal (IC) y determinar la presencia de huesos accesorios acompañantes. En 97 cráneos adultos de Anatolia, se identificó una sutura metópica en 31 especímenes (15 hombres, 16 mujeres). Se observó metopismo parcial en el 74,2 % (n = 23) y metopismo completo en el 25,8 % (n = 8), sin diferencias de sexo. En los cráneos con metopismo parcial, el tipo L fue el más común (39,1 %, n = 9), seguido del tipo V (34,8 %, n = 8) y el tipo H (26,1 %, n = 6). Una sutura premaxilar estuvo presente en el 22,6 % de los cráneos metópicos (n = 7), sin diferencias significativas por sexo (26,7 % en hombres, 18,8 % en mujeres) y sin asociación con el índice craneal. Se detectaron huesos accesorios en el 54,8 % (n = 17) y no se asociaron con el sexo, el estado de metopismo o el índice craneal. En conclusión, el IC no fue un predictor significativo de la presencia de la sutura premaxilar. Estos hallazgos proporcionan datos de prevalencia de referencia para el metopismo, la sutura premaxilar persistente y los huesos craneales accesorios en una muestra adulta de Anatolia, y pueden ser útiles para la interpretación anatómica y clínica.

PALABRAS CLAVE: Anatomía; Anomalías craneofaciales; Rasgos craneales; Sutura metópica; Metopismo; Análisis osteológico; Sutura premaxilar.

REFERENCES

Agarwal, S. K.; Malhotra, V. K. & Tewari, S. P. Incidence of the metopic suture in adult Indian crania. *Acta Anat. (Basel), 105(4)*:469-74, 1979.

Ajmani, M. L.; Mittal, R. K. & Jain, S. P. Incidence of the metopic suture in adult Nigerian skulls. *J. Anat., 137(Pt. 1)*:177-83, 1983.

Aldridge, K.; George, I. D.; Cole, K. K.; Austin, J. R.; Takahashi, T. N.; Duan, Y. & Miles, J. H. Facial phenotypes in subgroups of prepubertal boys with autism spectrum disorders are correlated with clinical phenotypes. *Mol. Autism, 2(1)*:15, 2011.

Ansari, A. & Bordoni, B. *Embryology, face*. In: StatPearls. Treasure Island (FL), StatPearls Publishing, 2024.

Ashley-Montagu, M. F. The medio-frontal suture and the problem of metopism in the primates. *J. R. Anthropol. Inst. G. B. Irel., 67*:157-201, 1937.

Ay, R.; Bhosale, S.; Naik, S. & Janvekar, M. Determination of craniofacial relation in human dry skulls: An anthropometric study. *Int. J. Health Clin. Res., 4*:209-13, 2021.

Baaten, P. J.; Haddad, M.; Abi-Nader, K.; Abi-Ghosn, A.; Al-Kutoubi, A. & Jurjus, A. R. Incidence of metopism in the Lebanese population. *Clin. Anat., 16(2)*:148-51, 2003.

Baresa, T.; Jerkovic, I.; Basic, Z.; Curic, A.; Dujic, G.; Dolic, K.; AnDelinovic, S.; Primorac, D. & Kruzic, I. Occurrence of metopic suture in modern and archaeological Croatian population. *Croat. Med. J., 65(3)*:174-9, 2024.

Barteczko, K. & Jacob, M. A re-evaluation of the premaxillary bone in humans. *Anat. Embryol. (Berl.), 207(6)*:417-37, 2004.

Beederman, M.; Farina, E. M. & Reid, R. R. Molecular basis of cranial suture biology and disease: Osteoblastic and osteoclastic perspectives. *Genes Dis., 1(1)*:120-5, 2014.

Bellary, S. S.; Steinberg, A.; Mirzayan, N.; Shirak, M.; Tubbs, R. S.; Cohen-Gadol, A. A. & Loukas, M. Wormian bones: A review. *Clin. Anat., 26(8)*:922-7, 2013.

Capote, R.; Preston, K. & Kapadia, H. Craniofacial growth and development: A primer for the facial trauma surgeon. *Oral Maxillofac. Surg. Clin. North Am., 35(4)*:501-13, 2023.

Castilho, M. A. S.; Oda, J. Y. & Sant'Ana, D. M. G. Metopism in adult skulls from Southern Brazil. *Int. J. Morphol., 24(1)*:61-6, 2006.

Cirpan, S.; Aksu, F.; Mas, N. & Magden, A. O. Coexistence of wormian bones with metopism, and vice versa, in adult skulls. *J. Craniofac. Surg., 27(2)*:493-5, 2016.

Cohen Jr., M. M. Sutural biology and the correlates of craniosynostosis. *Am. J. Med. Genet., 47(5)*:581-616, 1993.

da Silva, I. N.; Fernandes, K. J. M.; Ramalho, A. J. C.; Bispo, R. F. M.; Rodrigues, C. F. S. & Aragão, J. A. Occurrence of metopism in dry crania of adult Brazilians. *ISRN Anat, 2013*:158341, 2013.

Durge, S. V. Study of wormian bones on dry human skull and its sexual dimorphism in the region of Andhra Pradesh. *Indian J. Anat. Surg. Head Neck Brain, 2(3)*:79-82, 2016.

Elbizim, D. S.; Ortug, A.; Liman, Z. & Ortug, G. Nonmetric variants of Anatolian crania: A preliminary study. *J. Craniofac. Surg., 33(8)*, 2022.

Eroglu, S. The frequency of metopism in Anatolian populations dated from the Neolithic to the first quarter of the 20th century. *Clin. Anat., 21(6)*:471-8, 2008.

Flaherty, K.; Singh, N. & Richtsmeier, J. T. Understanding craniosynostosis as a growth disorder. Wiley Interdiscip. *Rev. Dev. Biol., 5(4)*:429-59, 2016.

Güler, H.; Güçlü Ekinci, H. K. & Kamas¸ak Arpaçay, B. Variation of wormian and Inca bones in adult skulls. *Eur. J. Ther., 30(3)*:332-9, 2024.

Gümüsburun, E.; Sevim, A.; Katkici, U.; Adigüzel, E. & Güleç, E. A study of sutural bones in Anatolian-Ottoman skulls. *Int. J. Anthropol., 12(2)*:43-8, 1997.

Hauser, G. *Epigenetic Variants of the Human Skull*. Stuttgart, E. Schweizerbart'sche Verlagsbuchhandlung (Nägele u. Obermiller), 1989.

Kilic-Safak, N.; Taskın Senol, R. & Yücel, A. Morphologic and morphometric evaluation of the wormian bones. *Int. J. Morphol., 38(1)*:69-73, 2020.

Knapp, E. & George, R. A survey of metopic suture persistence in the published literature. *J. Stud. Res., 11(4)*:1-8, 2023.

Krogman, W. M. & Iscan, M. Y. *The Human Skeleton in Forensic Medicine: Determination of Sex and Parturition.* Charles C. Thomas Publisher Ltd., 1986.

Li, B.; Wang, Y.; Fan, Y.; Ouchi, T.; Zhao, Z. & Li, L. Cranial suture mesenchymal stem cells: Insights and advances. *Biomolecules, 11(8)*, 2021.

Li, J. H.; Chen, Z. J.; Zhong, W. X.; Yang, H.; Liu, D. & Li, Y. K. Anatomical characteristics and significance of the metopism and wormian bones in dry adult-Chinese skulls. *Folia Morphol. (Warsz.), 82(1)*:166-75, 2023.

Linc, R. & Fleischmann, J. The occurrence of metopism in our present population and its relationship to sinus frontalis. *Anthropologie,* 35-40, 1969.

Lisson, J. A. & Kjaer, I. Location of alveolar clefts relative to the incisive fissure. *Cleft Palate Craniofac. J., 34(4)*:292-6, 1997.

Mann, R. W. & Hunt, D. R. Non-metric traits and anatomical variants that can mimic trauma in the human skeleton. *Forensic Sci. Int., 301*:202-24, 2019.

Manzanares, M. C.; Goret-Nicaise, M. & Dhem, A. Metopic sutural closure in the human skull. *J. Anat., 161*:203-15, 1988.

Martin, R. *Lehrbuch der Anthropologie in Systematischer Darstellung: Mit Besonderer Berücksichtigung der Anthropologischen Methoden für Studierende, Ärzte und Forschungsreisende.* 2nd ed. Vol. 2. Kraniologie, Osteologie. Jena, Gustav Fischer, 1928. pp.618-49.

Murlimanju, B. V.; Prabhu, L. V.; Pai, M. M.; Goveas, A. A.; Dhananjaya, K. V. & Somesh, M. S. Median frontal sutures - incidence, morphology and their surgical, radiological importance. *Turk. Neurosurg., 21(4)*:489-93, 2011.

Nicol, P.; Elmaleh-Bergès, M.; Sadoine, J.; Slimani, L. & Vacher, C. Incidence and morphology of the incisive suture in CT scanning of young children and human fetuses. *Surg. Radiol. Anat., 42(9)*:1057-62, 2020.

Nikolova, S.; Toneva, D.; Agre, G. & Lazarov, N. Influence of persistent metopic suture on sagittal suture closure. Ann. Anat., 239:151811, 2022.

Ortug, A. & Uzel, M. Greater palatine foramen: Assessment with palatal index, shape, number and gender. *Folia Morphol. (Warsz.), 78(2)*:371-7, 2019.

Özbek, Z. & Vural, M. Kranial sütürlerin biyolojisi, sütür büyüme, gelis¸me ve kapanmasının regülasyonu. *Türk Nöros¸ir. Derg., 27(3)*:245-50, 2017.

Pacífico, F. A.; Neto, D. R. L.; Silva, M. L.; Galvão, I. F. G. & de Farias Campina, R. C. Análise morfológica da persistência completa da sutura metópica em crânio braquicrânio: Um relato de caso. *Anais Fac. Med. Olinda, 1(13)*:1-9, 2025.

Padhy, N.; Patro, S.; Maharana, V. & Panda, R. A morphometric study on wormian bones in Southern Odisha population. *Int. J. Med. Public Health, 15(4)*, 2025.

Podstawka, M. L.; Czajka, A.; Zaczkowski, K.; Wisniewski, K. & Jaskolski, D. J. Metopic suture: Formation and clinical implications - a review. *Aktualn. Neurol., 24(1)*:40-5, 2024.

Posnick, J. C. *Hereditary, Developmental, and Environmental Influences on the Formation of Dentofacial Deformities*. In: Posnick, J. C. Orthognathic Surgery: Principles and Practice. Amsterdam, Elsevier, 2014. pp.69-134.

Richtsmeier, J. T. & Flaherty, K. Hand in glove: Brain and skull in development and dysmorphogenesis. *Acta Neuropathol., 125(4)*:469-89, 2013.

Roth, D. M.; Bayona, F.; Baddam, P. & Graf, D. Craniofacial development: Neural crest in molecular embryology. *Head Neck Pathol., 15(1)*:1-15, 2021.

Ruiz-Correa, S.; Sze, R. W.; Starr, J. R.; Lin, H. T.; Speltz, M. L.; Cunningham, M. L. & Hing, A. V. New scaphocephaly severity indices of sagittal craniosynostosis: A comparative study with cranial index quantifications. *Cleft Palate Craniofac. J., 43(2)*:211-21, 2006.

Schaurich, C. G.; Saraco, A. N.; Oruganti, M. H.; Tamber, M. S.; Haetinger, R. G.; Dixit, I.; Lo, B. S. Y.; Krebs, C. & Steinbok, P. Allometry of human calvaria bones during development from birth to 8 years of age shows a nonlinear growth pattern. *Sci. Rep., 14(1)*:26205, 2024.

Sharma, S.; Krishna, H.; Dixit, S. G. & Ghatak, S. Metopism and its clinical relevance: A persistent suture. *Ann. Afr. Med., 24(1)*:19-21, 2024.

Skrzat, J.; Walocha, J. & Zawilinski, J. A note on the morphology of the metopic suture in the human skull. *Folia Morphol. (Warsz.), 63(4)*:481-4, 2004.

Som, P. M. & Naidich, T. P. Illustrated review of the embryology and development of the facial region, part 2: Late development of the fetal face and changes in the face from the newborn to adulthood. *AJNR Am. J. Neuroradiol., 35(1)*:10-8, 2014.

Sperber, G. H. *Head and Neck Embryology*. In: Serletti, J. M. (Ed.). Current Reconstructive Surgery. New York, McGraw-Hill Medical, 2013. pp.113-24.

Tapadia, M. D.; Cordero, D. R. & Helms, J. A. It's all in your head: New insights into craniofacial development and deformation. *J. Anat., 207(5)*:461-77, 2005.

Torgersen, J. A roentgenological study of the metopic suture. *Acta Radiol., 33(1)*:1-11, 1950.

Trevizan, M. & Consolaro, A. Premaxilla: An independent bone that can base therapeutics for middle third growth! *Dental Press J. Orthod., 22(2)*:21-6, 2017.

Trevizan, M.; Nelson Filho, P.; Franzolin, S. O. B. & Consolaro, A. Premaxilla: Up to which age it remains separated from the maxilla by a suture, how often it occurs in children and adults, and possible clinical and therapeutic implications: Study of 1,138 human skulls. *Dental Press J. Orthod., 23(6)*:16-29, 2018.

van der Meulen, J. Metopic synostosis. *Childs Nerv. Syst., 28(9)*:1359-67, 2012.

Vega, Y. M.; Rojas-Granados, A.; Arellano-Rivera, E.; Martínez-Díaz, A.; Méndez, O. L. & Angeles-Castellanos, M. Metopism: An anatomical variant that the physician should take into account. *Int. J. Case Rep. Images, 15(1)*:82-6, 2024.

Vinchon, M. The metopic suture: Natural history. *Neurochirurgie, 65(5)*:239-45, 2019.

Vu, H. L.; Panchal, J.; Parker, E. E.; Levine, N. S. & Francel, P. The timing of physiologic closure of the metopic suture: A review of 159 patients using reconstructed 3D CT scans of the craniofacial region. *J. Craniofac. Surg., 12(6)*, 2001.

White, H. E.; Goswami, A. & Tucker, A. S. The intertwined evolution and development of sutures and cranial morphology. *Front. Cell Dev. Biol., 9*:653579, 2021.

Williams, B. A. & Rogers, T. Evaluating the accuracy and precision of cranial morphological traits for sex determination. *J. Forensic Sci., 51(4)*:729-35, 2006.

Wróbel, G. The human adult skull with complete metopic suture – a case report. *J. Educ. Health Sport, 7(9)*:370-6, 2017.

Yadav, A.; Kumar, V. & Srivastava, R. K. Study of metopic suture in the adult human skulls of North India. *J. Anat. Soc. India, 59(2)*:232-6, 2010.

Zdilla, M. J.; Russell, M. L.; Koons, A. W.; Bliss, K. N. & Mangus, K. R. Metopism: A study of the persistent metopic suture. *J. Craniofac. Surg., 29(1)*:204-8, 2018.

Corresponding author:
Prof. Dr. Dr. Gursel Ortug, DMD, PhD
Emeritus Professor of Anatomy
School of Medicine
Bahcesehir University
Istanbul
TURKIYE

Email: gurselortug@gmail.com