



Distribution of frontal sinus pattern amongst Malaysian population: a skull radiograph study

Nur Damia Iwani Zulkiflee¹, Mansharan Kaur Chainchel Singh^{2,3}, Aspalilah Alias^{4,5,6},
Helmi Mohd Hadi Pritam⁷, Eric Chung⁸, Rani Sakaran⁹, Nurul Hannim Zaidun¹, Choy Ker Woon¹

¹Department of Anatomy, Faculty of Medicine, Universiti Teknologi MARA, Selangor, ²Institute of Pathology, Laboratory and Forensic Medicine (I-PPerForM), Faculty of Medicine, Universiti Teknologi MARA, Selangor, ³Department of Radiology, Faculty of Medicine, Universiti Teknologi MARA, Selangor, ⁴Department of Basic Sciences and Oral Biology, Faculty of Dentistry, Universiti Sains Islam Malaysia, Kuala Lumpur, Malaysia, ⁵Forensic Odontology Unit, Department of Imaging & Pathology, KU Leuven, Leuven, Belgium, ⁶Department of Forensic Odontology, Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia, ⁷Forensic Unit, School of Health Sciences, Universiti Sains Malaysia, Kelantan, ⁸Department of Biomedical Imaging, University Malaya Medical Centre, Kuala Lumpur, ⁹Department of Anatomy, Asian Institute of Medicine, Science and Technology (AIMST), Kedah, Malaysia

Abstract: Frontal sinus has unique anatomical features that are distinct to every population. However, the distribution of frontal sinus patterns has yet to be explored in the Malaysian population. This study aimed to describe the distribution of frontal sinus patterns among adult Malaysians. 409 adult Malaysian posteroanterior skull radiographs, consisting of 200 males and 209 females of Malay, Chinese, and Indian races aged between 20–69 years old, were included in the study. The frontal sinus patterns were classified according to total and percentage of presence or absence of frontal sinus, symmetry or asymmetrical (right or left dominant), unilateral absence (right or left), bilateral absence, and lobulation. The findings showed that bilateral presence of frontal sinus is common, in 95.4% of individuals and bilateral absence was noted in 2.7% individuals. Unilateral absence was found in 2.0% of individuals. Asymmetrical frontal sinus was observed in 54.5% of population meanwhile 40.8% showed symmetrical frontal sinus. The majority of individuals, regardless of sex, race, and age, possessed 1 to 3 lobes on both sides of the frontal sinus. The findings suggest that the frontal sinus is highly asymmetric, and the absence of the frontal sinus is rare. This morphological variation provides an insight into the landmarking placement for measurement during forensic application and assists neurosurgeons in surgical procedure to avoid breaching of the frontal sinus.

Key words: Forensic anthropology, Frontal sinus, Malaysian, Radiograph

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Introduction

The frontal sinus is a pneumatized cavity that is present inside the frontal bone of the skull [1, 2]. The frontal sinus often appears as two irregular cavities extending upward and

laterally into squama frontalis [3]. It is seldom symmetrical, as the left and right lobes are separated by a central septum causing both lobes to develop independently and deviate from the midline [4]. The sinus is divided into several lobes by the formation of partial bony septa. The frontal sinus is not visible at birth and begins its development during the second year of life [5]. It is radiographically detected after further pneumatization that takes up to five to eight years of life [6]. The development is completed by the 20th year of life, and it occurs earlier in girls than boys. The frontal sinus development remains stable throughout adult life until further slight enlargement which may occur from bone resorp-

Corresponding author:

Choy Ker Woon 
Department of Anatomy, Faculty of Medicine, Universiti Teknologi
MARA, Selangor 47000, Malaysia
E-mail: choykerwoon@uitm.edu.my

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tion during advanced age [6].

The morphological variation of the frontal sinus has both surgical and forensic significance [7]. In the case of the surgical field, frontal sinus is frequently accessed during neurosurgical procedures on the frontal bone (*i.e.*, supraorbital and pterional craniotomies) however, due to the close relationship between the frontal sinus and the anterior skull base or orbit, the frontal sinus may be susceptible to surgical complications [7]. Breaching of the frontal sinus should be avoided to reduce the risk of postoperative complications such as a cerebrospinal fluid leak, sinusitis and mucocoeles development [8]. For this reason, a thorough knowledge of the complex anatomy, anomalies and variations of the frontal sinus is vital for neurosurgeons to avoid complications and maximise the success of neurosurgical procedures [8]. This can be particularly helpful in preoperative planning and deciding on the appropriate neurosurgical approach [7].

In the forensic field, the use of frontal sinus in identifying human skeletal remains is increasingly applied and recognised in forensic investigation [3, 9]. The significance of frontal sinus in forensic identification lies in its unique pattern [10]. Analogous to the fingerprint, frontal sinus is unique between each individual, even in the case of monozygotic twins [11]. Since the frontal sinus is commonly used for comparison of ante- and post-mortem radiographs technique in forensic investigation, the capability of the frontal sinus to remain stable throughout the lifespan will help the frontal sinus not be affected by the time elapsed of the post-mortem [9, 12]. One or both sides of the frontal sinuses may be absent occasionally [1]. The low incidence of frontal sinus absence is regarded as another vital morphological feature for establishing a definite and reliable biological profile [1]. Being an internal body structure, the arched feature protects the frontal sinus from decomposition and damage, allowing the frontal sinus to preserve intact in human skeletal remains [13]. These highlights the need to further explore the distribution of frontal sinus patterns, especially amongst the Malaysian population.

The unique pattern of the frontal sinus (*i.e.*, symmetry and asymmetry) was initially observed by Zuckerkandl in 1895. Later, Culbert and Law were the first to describe human identification through morphological variation of the frontal sinus, which then was accepted in a United States court of law [4]. In the Indian population, the frontal sinus morphology was unique and highly symmetrical (85.9%) among the male sex group (48.4%) [13], contrary to the Saudi

population, which presented greater symmetrical patterns (83.2%) among the female sex group (43.0%) [15]. Despite various studies conducted in diversified populations to test the reliability of frontal sinus for personal identification, studies regarding frontal sinus morphology among sex, race and age profiles of the Malaysian population have yet to be explored. In this study, the distribution and variability of frontal sinus patterns among Malaysians were observed.

Materials and Methods

Data collection

This cross-sectional study was conducted using skull radiographs retrieved retrospectively from the Department of Biomedical Imaging, University of Malaya Medical Centre (UMMC), from 2015 to 2021. The digital radiographs were extracted into Digital Imaging and Communications in Medicine (DICOM) and Joint Photographic Experts Group (JPEG) format to analyse the frontal sinus pattern. Ethics approval was obtained from the UMMC-Medical Research Ethics Committee (MREC) (MECID No: 2022119-10937).

Study population

A total of 409 posteroanterior (PA) skull radiographs were collected based on the sex subgroups (*i.e.*, male and female), Malaysian ancestry subgroups (*i.e.*, Malay, Chinese, and Indian) and age subgroups (Group I, II, III, IV, V) ranging from 20–69 years old. The age was classified into five groups which are Group I (20–29 years old), II (30–39 years old), III (40–49 years old), IV (50–59 years old), and V (60–69 years old) [6]. The study included good quality radiographs with no apparent sinonasal pathology. Cases with a history of maxillofacial trauma, clinical characteristics of bone diseases and non-Malaysian were excluded after being reviewed by the radiologist. This study excluded the paediatric samples and covered cases of the adult population as the development of frontal sinus was completed at the 20th year of life.

Classification of frontal sinus pattern

Personal identifying information such as the name and identity card number of the samples were removed, and each sample was allocated a unique code to maintain the privacy of the subjects. Parameters such as sex, race, and age were recorded. The frontal sinus pattern was classified according to the presence or absence of the frontal sinus (Figs. 1, 2). For the group with the presence of frontal sinus, it was further

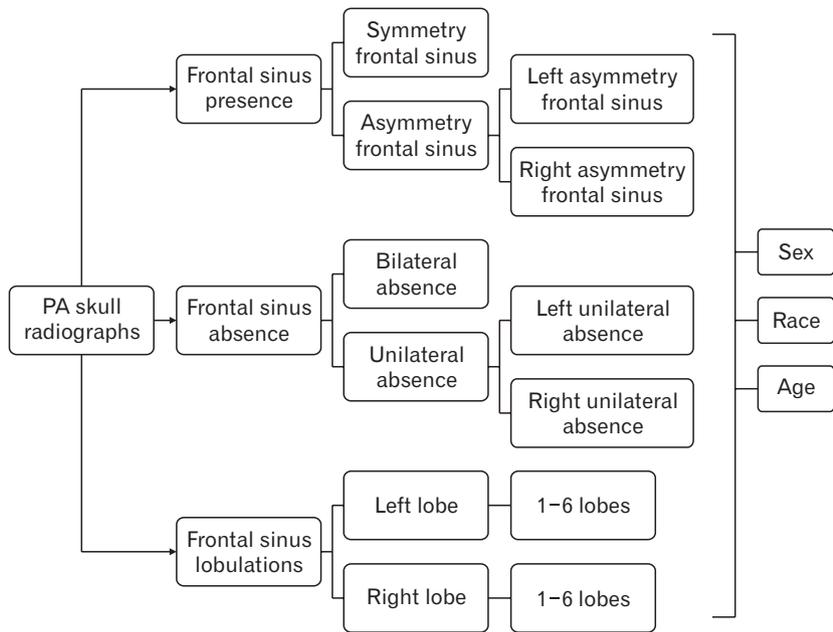


Fig. 1. Classification of frontal sinus pattern.

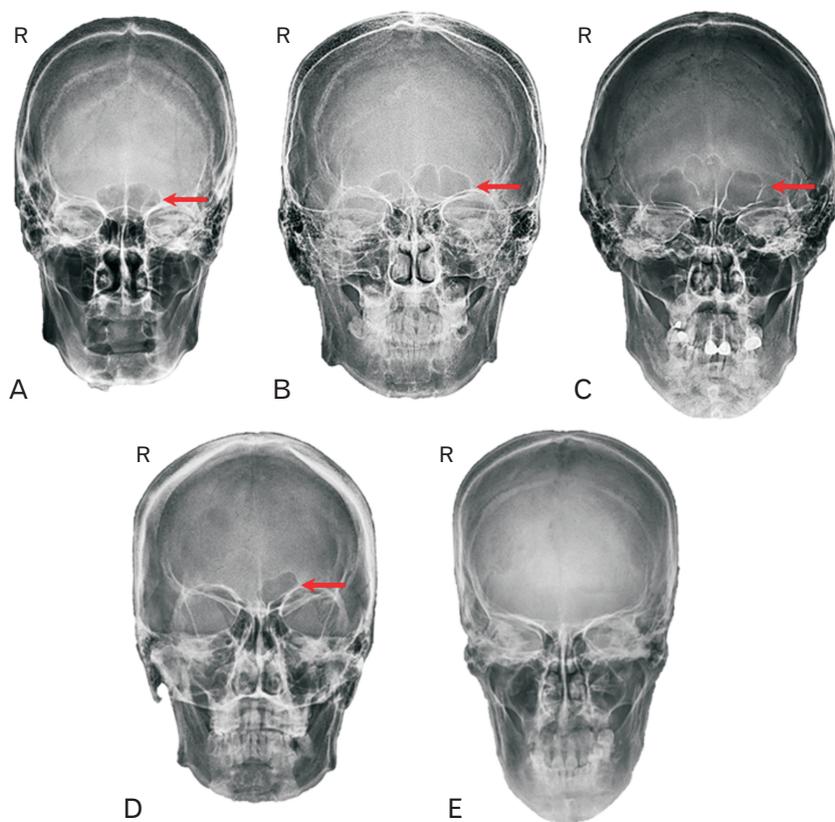


Fig. 2. Various frontal sinus patterns: (A) symmetrical, (B) left asymmetry, (C) right asymmetry, (D) unilateral absence, and (E) bilateral absence. Red arrows shows frontal sinus. R, right side.

categorised if the frontal sinus is symmetrical or asymmetrical. For asymmetrical frontal sinus, the dominant side was determined by the sloping of the central septum (septum

that separates the left and right frontal sinus) either to the left or right side of the frontal sinus [1]. The central septum that stays in the midline is considered a symmetry frontal

sinus [1]. For groups with the absence of frontal sinus, it was categorised if it was unilateral (right or left) or bilateral absence. The number of lobulations on both sides of the frontal sinus was recorded. The radiographs were examined on the computer using RadiAnt DICOM Viewer version 2021.2 (Medixant, Poznan, Poland).

Data analysis

All data were exported into Microsoft Excel 365 ver. 2201 (Microsoft, New Mexico, NM, USA), and the total number and percentage of pattern distribution were tabulated.

Results

Demographic data

The total studied subjects consisted of 409 PA skull radiographs. The results were based on three biological profiles: sex (*i.e.*, 200 male [48.9%] and 209 female [51.1%]) (Table 1), race (*i.e.*, 136 Malay [33.3%], 138 Chinese [33.7%], and 135

Indian [33.0%]) (Table 2), and age groups (*i.e.*, 82 group I [20.0%], 79 group II [19.3%], 83 group III [20.3%], 82 group IV [20.0%], and 83 group V [20.3%]) (Table 3). Among the Malay subjects, there were 68 males (50.0%) as well as 68 females (50.0%) (Table 2). Among the Chinese subjects, there were 66 males (47.8%) and 72 females (52.2%), and among Indian subjects, there were 66 males (48.9%) and 69 females (51.1%) (Table 2). Malay males were dominated by age group I population with 15 (22.1%) subjects (Table 3). Meanwhile, Malay females comprised the most of age group IV with 15 (22.1%) subjects (Table 3). For Chinese males, most subjects were found to be in the age group I, with 14 (21.2%) subjects (Table 3). Meanwhile, for Chinese females, most subjects were from age group V with 16 (22.2%) subjects (Table 3). Both Indian males and Indian females were dominated by age group III, with 14 (21.2%) and 15 (21.7%) subjects, respectively (Table 3).

The overall percentage of bilateral frontal sinus presence

Table 1. Distribution of samples by sex groups

Sex	Value
Male	200 (48.9)
Female	209 (51.1)
Total	409 (100)

Values are presented as number (%).

Table 2. Distribution of samples by race groups

Parameter	Race		
	Malay	Chinese	Indian
Sex			
Male	68 (50.0)	66 (47.8)	66 (48.9)
Female	68 (50.0)	72 (52.2)	69 (51.1)
Total	136 (33.3)	138 (33.7)	135 (33.0)

Values are presented as number (%).

Table 3. Distribution of samples by age groups

Parameter	Age group (age range)				
	I (20–29 yr)	II (30–39 yr)	III (40–49 yr)	IV (50–59 yr)	V (60–69 yr)
Malay					
Male	15 (22.1)	13 (19.1)	13 (19.1)	14 (20.6)	13 (19.1)
Female	13 (19.1)	13 (19.1)	13 (19.1)	15 (22.1)	14 (20.6)
Chinese					
Male	14 (21.2)	13 (19.7)	13 (19.7)	13 (19.7)	13 (19.7)
Female	14 (19.4)	14 (19.4)	15 (20.8)	13 (18.1)	16 (22.2)
Indian					
Male	13 (19.7)	13 (19.7)	14 (21.2)	13 (19.7)	13 (19.7)
Female	13 (18.8)	13 (18.8)	15 (21.7)	14 (20.3)	14 (20.3)
Total	82 (20.0)	79 (19.3)	83 (20.3)	82 (20.0)	83 (20.3)

Values are presented as number (%).

Table 4. Distribution of frontal sinus patterns between sex groups (male=200, female=209)

Sex group	Frontal sinus presence				Frontal sinus absence				Grand total
	Symmetry	Asymmetry		Total	Bilateral absence	Unilateral absence		Total	
		Right dominant	Left dominant			Right absence	Left absence		
Male (n=200)	73 (36.5)	46 (23.0)	76 (38.0)	195 (97.5)	2 (1.0)	1 (0.5)	2 (1.0)	5 (2.5)	200 (100)
Female (n=209)	94 (45.0)	30 (14.4)	71 (34.0)	195 (93.3)	9 (4.3)	5 (2.4)	0 (0)	14 (6.7)	209 (100)
Total	167 (40.8)	76 (18.5)	147 (36.0)	390 (95.4)	11 (2.7)	6 (1.5)	2 (0.5)	19 (4.6)	409 (100)

Values are presented as number (%).

was 95.4%, the bilateral absence was 2.7%, and the unilateral absence was 2.0%. Of all cases with the presence of frontal sinus, 40.8% showed a symmetrical pattern, whilst 36.0% and 18.5% of the individuals demonstrated left and right asymmetry, respectively (Table 4).

Distribution of frontal sinus patterns by sex groups

Bilateral presence of frontal sinus was observed in 195 males (97.5%) and 195 females (93.3%) (Table 4). The presence of the frontal sinus was then further observed for its symmetry by evaluating the sloping of the central septum. Fig. 3 showed that 36.5% of males and 45.0% of females have symmetrical frontal sinus with the central septum in the midline. Meanwhile, 23.0% of males and 14.4% of females showed that the central septum slopes to the left side of the midline, followed by 38.0% of males and 34.0% of females where the central septum slopes to the right side, indicating

right and left dominant asymmetry, respectively.

The absence of frontal sinus is more common in females (6.7%) than males (2.5%) (Fig. 3). The absence of frontal sinus was classified further into bilateral absence and unilateral absence. Bilateral absence was more commonly seen in females (4.3%) when compared to males (1.0%). Right unilateral absence was observed in 0.5% of males and 2.4% of females, and left unilateral absence was only seen in males (1.0%) (Fig. 3). The lobulations of the male’s frontal sinus mostly showed one to two lobes on the right side (33.5%) and two lobes on the left side (31.5%). Meanwhile, females had one lobe on the right side (38.3%) and two lobes on the left side (44.5%) (Table 5).

Distribution of frontal sinus patterns by race groups

The studied subjects comprised 136 Malays, 138 Chinese, and 135 Indians. The bilateral presence of frontal sinus cases

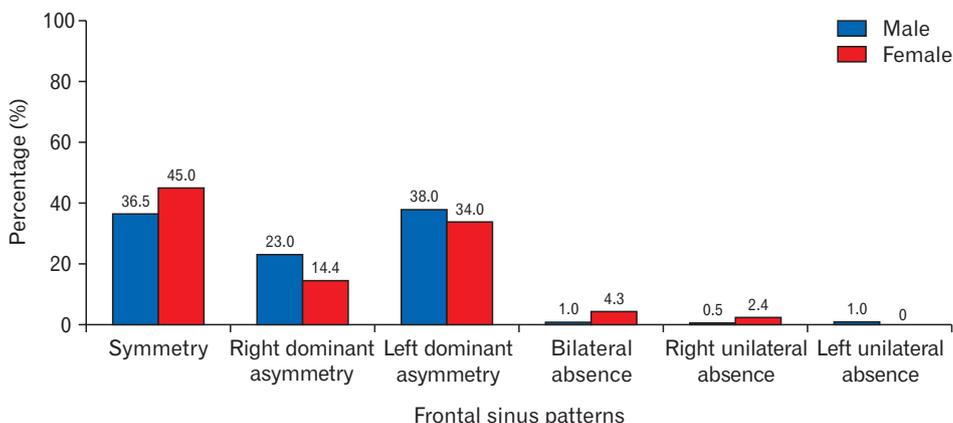


Fig. 3. Bar graph of frontal sinus patterns distribution between sex groups, males (n=200) and females (n=209).

Table 5. Distribution of frontal sinus lobulations between sex groups

Sex group	Lobes												Total	
	Number of lobes at right frontal sinus						Number of lobes at left frontal sinus							
	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
Male	67 (33.5)	67 (33.5)	42 (21.0)	15 (7.5)	6 (3.0)	0 (0)	197 (98.5)	48 (24.0)	63 (31.5)	56 (28.0)	20 (10.0)	8 (4.0)	1 (0.5)	196 (98.0)
Female	80 (38.3)	72 (34.4)	31 (14.8)	11 (5.3)	0 (0)	1 (0.5)	195 (93.3)	50 (23.9)	93 (44.5)	44 (21.1)	10 (4.8)	3 (1.4)	0 (0)	200 (95.7)
Total	147 (36.0)	139 (34)	73 (17.8)	26 (6.4)	6 (1.5)	1 (0.2)	392 (95.8)	98 (23.9)	156 (38.1)	100 (24.5)	30 (7.3)	11 (2.7)	1 (0.2)	396 (96.8)

Values are presented as number (%).

Table 6. Distribution of frontal sinus patterns between race groups

Race group	Frontal sinus presence				Frontal sinus absence				Grand total
	Symmetry	Asymmetry		Total	Bilateral absence	Unilateral absence		Total	
		Right dominant	Left dominant			Right absence	Left absence		
Malay (n=136)	60 (44.1)	27 (19.9)	43 (31.6)	130 (95.6)	3 (2.2)	1 (0.7)	2 (1.5)	6 (4.4)	136 (100)
Chinese (n=138)	50 (36.2)	19 (13.8)	61 (44.2)	130 (94.2)	5 (3.6)	3 (2.2)	0	8 (5.8)	138 (100)
Indian (n=135)	57 (42.2)	30 (22.2)	43 (31.9)	130 (96.3)	3 (2.2)	2 (1.5)	0	5 (3.7)	135 (100)
Total	167 (40.8)	76 (18.5)	147 (36.0)	390 (95.4)	11 (2.7)	6 (1.5)	2 (0.5)	19 (4.6)	409 (100)

Values are presented as number (%).

were observed the most among Indians (96.3%), followed by Malays (95.6%) and Chinese (94.2%), as shown in Table 6. Of all included cases, Malay showed the highest percentage of frontal sinus symmetry (44.1%), followed by Indian (42.2%) and Chinese (36.2%) (Fig. 4). Conversely, the Chinese race was often found with left dominated asymmetry (44.2%), and Indians conquered the right dominant asymmetry patterns (22.2%) (Fig. 4). The total absence of frontal sinus was noticed the most among Chinese (5.8%), followed by Malays (4.4%), whereas Indians (3.7%) were the least appeared with frontal sinus absence (Table 6). A closer inspection of Table 7 showed the right frontal sinus of both Malay and Chinese had one lobe (Malay: 40.4% and Chinese: 35.5%), and Indians possessed two lobes (34.1%). Meanwhile, on the left side, all three races mostly had two lobes (Malay: 36.8%, Chinese:

37.0%, and Indian: 40.7%).

Distribution of frontal sinus patterns by age groups

The obtained samples were divided into age groups I, II, III, IV, and V, as shown in Table 8. Each age group consisted of 82, 79, 83, 82, and 83 samples, respectively. Among the included cases, the age group III (44.6%) was often showing symmetry frontal sinus (Fig. 5). Whilst the right and left dominant asymmetry were found the most among group V (22.9%) and group II (39.2%), respectively (Fig. 5). However, the left dominant asymmetry was more commonly found than the dominant right asymmetry (Table 8). The absence of frontal sinus among age groups is random. Bilateral absence is most typically seen in age group V (4.8%). Right unilateral absence was found after age range 30–39 years old

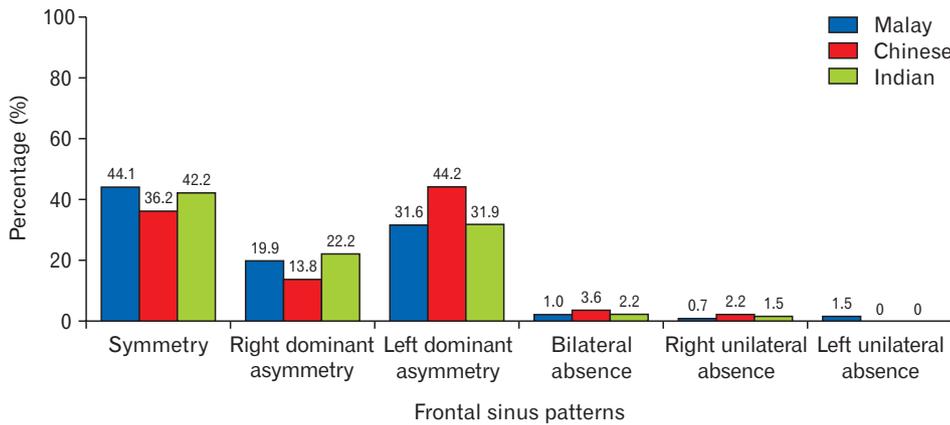


Fig. 4. Bar graph of frontal sinus patterns distribution between race groups, Malays (n=136), Chinese (n=138), and Indians (n=135).

Table 7. Distribution of frontal sinus lobulations between race groups

Race group	Lobes													
	Number of lobes at right frontal sinus						Total	Number of lobes at left frontal sinus						Total
	1	2	3	4	5	6		1	2	3	4	5	6	
Malay	55 (40.4)	45 (33.1)	24 (17.6)	8 (5.9)	0 (0)	0 (0)	132 (97.1)	36 (26.5)	50 (36.8)	33 (24.3)	11 (8.1)	1 (0.7)	0 (0)	131 (96.3)
Chinese	49 (35.5)	48 (34.8)	22 (15.9)	7 (5.1)	3 (2.2)	1 (0.7)	130 (94.2)	30 (21.7)	51 (37.0)	34 (24.6)	9 (6.5)	9 (6.5)	0 (0)	133 (96.4)
Indian	43 (31.9)	46 (34.1)	27 (20.0)	11 (8.1)	3 (2.2)	0 (0)	130 (96.3)	32 (23.7)	55 (40.7)	33 (24.4)	10 (7.4)	1 (0.7)	1 (0.7)	132 (97.8)
Total	147 (36.0)	139 (34)	73 (17.8)	26 (6.4)	6 (1.5)	1 (0.2)	392 (95.8)	98 (23.9)	156 (38.1)	100 (24.5)	30 (7.3)	11 (2.7)	1 (0.2)	396 (96.8)

Values are presented as number (%).

Table 8. Distribution of frontal sinus patterns between age groups

Age groups ^{a)}	Frontal sinus presence				Frontal sinus absence				Grand total
	Symmetry	Asymmetry		Total	Bilateral absence	Unilateral absence		Total	
		Right dominant	Left dominant			Right absence	Left absence		
Group I (n=82)	33 (40.2)	16 (19.5)	29 (35.4)	78 (95.1)	3 (3.7)	0	1 (1.2)	4 (4.9)	82 (100)
Group II (n=79)	32 (40.5)	15 (19.0)	31 (39.2)	78 (98.7)	1 (1.3)	0	0	1 (1.3)	79 (100)
Group III (n=83)	37 (44.6)	12 (14.5)	29 (34.9)	78 (94.0)	2 (2.4)	3 (3.6)	0	5 (6.0)	83 (100)
Group IV (n=82)	34 (41.5)	14 (17.1)	30 (36.6)	78 (95.1)	1 (1.2)	2 (2.4)	1 (1.2)	4 (4.9)	82 (100)
Group V (n=83)	31 (37.3)	19 (22.9)	28 (33.7)	78 (94.0)	4 (4.8)	1 (1.2)	0	5 (6.0)	83 (100)
Total	167 (40.8)	76 (18.5)	147 (36.0)	390 (95.4)	11 (2.7)	6 (1.5)	2 (0.5)	19 (4.6)	409 (100)

Values are presented as number (%). ^{a)}Age range: group I, 20–29 yr; group II, 30–39 yr; group III, 40–49 yr; group IV, 50–59 yr; group V, 60–69 yr.

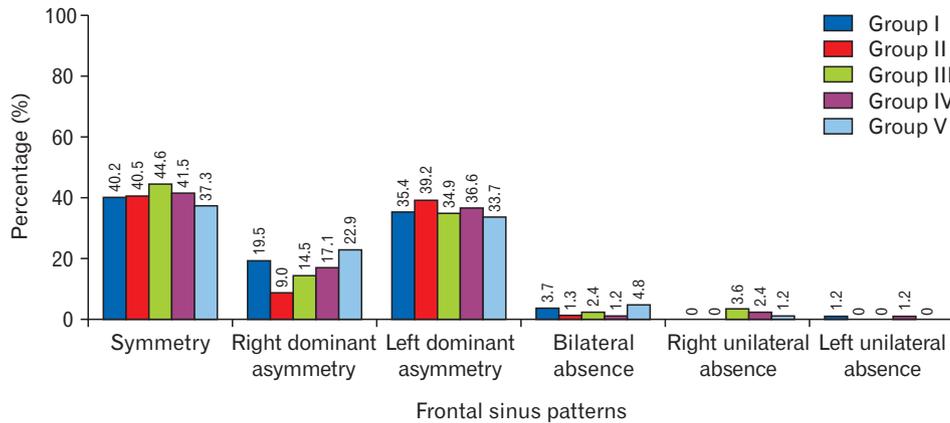


Fig. 5. Bar graph of frontal sinus patterns distribution between age groups, group I (n=82), group II (n=79), group III (n=83), group IV (n=82), and group V (n=83). Age range: group I, 20–29 yr; group II, 30–39 yr; group III, 40–49 yr; group IV, 50–59 yr; group V, 60–69 yr.

Table 9. Distribution of frontal sinus lobulations between age groups

Age Group	Lobes													
	Number of lobes at right frontal sinus						Total	Number of lobes at left frontal sinus						Total
	1	2	3	4	5	6		1	2	3	4	5	6	
Group I	20 (24.4)	36 (43.9)	15 (18.3)	6 (7.3)	2 (2.4)	0 (0)	79 (96.3)	19 (23.2)	24 (29.3)	26 (31.7)	7 (8.5)	2 (2.4)	0 (0)	78 (95.1)
Group II	31 (39.2)	26 (32.9)	16 (20.3)	5 (6.3)	0 (0)	0 (0)	78 (98.7)	18 (22.8)	35 (44.3)	15 (19.0)	6 (7.6)	3 (3.8)	1 (1.3)	78 (98.7)
Group III	31 (37.3)	28 (33.7)	14 (16.9)	4 (4.8)	1 (1.2)	0 (0)	78 (94.0)	24 (28.9)	32 (38.6)	19 (22.9)	5 (6.0)	1 (1.2)	0 (0)	81 (97.6)
Group IV	34 (41.5)	23 (28.0)	16 (19.5)	3 (3.7)	3 (3.7)	0 (0)	79 (96.3)	19 (23.2)	31 (37.8)	21 (25.6)	7 (8.5)	2 (2.4)	0 (0)	80 (97.6)
Group V	31 (37.3)	26 (31.3)	12 (14.5)	8 (9.6)	0 (0)	1 (1.2)	78 (94.0)	18 (21.7)	34 (41.0)	19 (22.9)	5 (6.0)	3 (3.6)	0 (0)	79 (95.2)
Total	147 (36.0)	139 (34)	73 (17.8)	26 (6.4)	6 (1.5)	1 (0.2)	392 (95.8)	98 (23.9)	156 (38.1)	100 (24.5)	30 (7.3)	11 (2.7)	1 (0.2)	396 (96.8)

Values are presented as number (%). ^aAge range: group I, 20–29 yr; group II, 30–39 yr; group III, 40–49 yr; group IV, 50–59 yr; group V, 60–69 yr.

(Fig. 5). Meanwhile, the left unilateral absence was only seen in the age group I (1.2%) and IV (1.2%) (Fig. 5), presenting the same distribution. Table 9 indicates that the youngest age group often presented with two lobes (43.9%) on the right side and three lobes (31.7%) on the left side. Whilst the rest of the age groups have one lobe on the right side (group II: 39.2%, group III: 37.3%, group IV: 41.5%, and group V: 37.3%) and two lobes on the left side (group II: 44.3%, group III: 38.6%, group IV: 37.8%, and group V: 41.0%).

Discussion

The morphological variation of the frontal sinus can be crucial for forensic investigation and for a neurosurgeon in planning the pterional and supra-orbital craniotomy due to the proximity of the frontal sinus to the orbit and the anterior skull base [7]. The present study highlighted the findings on the morphological variation of frontal sinus patterns in relation to sex, race, and age groups of Malaysians. The right and left frontal sinuses develop separately, and one or more cells are formed on each side, separated by partial septa [16]. Consequently, the frontal sinuses may appear asymmetrical due to the independent development or not develop at all.

It is not uncommon to find an absent frontal sinus [7]. The percentage of bilateral absence of frontal sinus was 2.7% in the Malaysian population, which is relatively similar to other Asian populations, like Verma et al. [4], which reported 5.4% non-existence of frontal sinus in the South Indian population. Similarly, Patil et al. [11] had found bilateral aplasia of only 1.0% among the North Indian population. There were 2.0% unilateral absence cases in our study, which is similarly low compared to Indian and Ireland populations, with 4.3% and 2.0% of total unilateral absence, respectively [1]. Among 2.0% of total unilateral cases, the left frontal sinus was absent in two cases, and the right was absent in six cases. Overall, the absence of frontal sinus occurred in only 19 cases.

This current study demonstrated that the presence of frontal sinus was found in 95.4% of the subjects, and symmetrical frontal sinus comprised 40.8% of the total cases. In contrast, Verma et al. [4] showed that there was 78.5% symmetry in the Indian population, and in a study by Shireen et al. [15], symmetrical frontal sinus was noted in 83.2% of the Saudi population samples, suggesting that the majority of the Indian and Saudi population have more symmetrical frontal sinus compared to Malaysians. In our study, asymmetry

cases were seen in 54.5% of samples. The results were consistent with those studies by Taniguchi et al. [17], who obtained 43.1% in the Japanese population. David and Saxena [14] reported symmetry frontal sinus in 58.0% of subjects in the Indian population. The discrepancy between percentage frequency in this study and other preceding studies may be due to environmental factors (*i.e.*, climates of different countries) and individual health that might affect the variability of the frontal sinus pattern among different populations [4]. The climatic factor on the frontal sinus morphology is speculated to be associated with heat retention and insulation that occurs in cold environments that contribute to the smaller size and absence of the frontal sinus [18].

Our study demonstrated that the frontal sinus exhibits morphological variability between both sexes. The absence of frontal sinus is greater in females (6.7%) compared to males (2.5%), and this finding is in accordance with the findings of the Indian population (male: 4% and female: 12%), Japanese population (male: 13% and female: 23%), and Turkish population (male: 1.3% and female: 5.0%) [1].

The central septa of the frontal sinus in this current study presented that majority of males had central septa sloping toward the right (38.0%) and left (23.0%), indicating the left and right asymmetry. The result is similar to Verma et al. [4], who reported that males mostly appeared with asymmetry frontal sinus (left asymmetry: 2.7%, and right asymmetry: 0.9%). The sloping of the central septum is due to the independent development of both sides of the frontal sinus, leading to the existence of one side being larger and crossing the midline [1, 15]. The symmetry of the frontal sinus is commonly seen amongst females, 45.0% out of the total samples. This is consistent with what has been found in previous studies among the South Indian population [4, 14], with 39% and 32.0% of the females, respectively. Data on lobulations shows frontal sinus with 3 to 5 lobes often appears among males compared to females. A similar presentation was seen in the Indian population [4].

The morphological variation of frontal sinus was evaluated among three main races of the Malaysian population (*i.e.*, Malay, Chinese, and Indian) in the present study. The frontal sinus was absent in the majority of the Chinese race, with 5.8%. Malay individuals demonstrated symmetry patterns of 44.1%, and Indian and Chinese showed 42.2% and 36.2% symmetry patterns, respectively. This suggested that Malay typically have symmetrical frontal sinus more often than other races. Chinese (44.2%) most commonly have a

central septum sloping to the right side, whereas Indians (22.2%) often have a central septum sloping to the left side, suggesting right asymmetry of the frontal sinus. In other populations, the pattern's variation among the New Mexican population demonstrates that Black individuals often showed right asymmetry than White individuals [19]. The inconsistency of the distribution of frontal sinus among races may be explained by genetic factors [4]. The distribution of lobulations among these three races is random. Though, all races commonly have one to three lobes on both sides of the frontal sinus. To date, the discussion among race groups is limited due to the limitation of literature regarding the relationship between frontal sinus morphology and ancestry [20]. The frontal sinus patterns variation of the three main races among Malaysian have not been analysed and compared against one another in this manner.

This study revealed the variation of frontal sinus morphology in different age groups. The cases of absent frontal sinus are typically seen among those in the age group III and V, with 6.0% of the subjects. Symmetry cases were seen as the highest in age group III (44.6%). Whilst percentage of central septum slopes to the left and right side is often found in age groups V (22.9%) and II (39.2%), respectively. Despite the unpredictable distribution of lobulations, all the age groups typically appeared with one to three lobes on both sides of the frontal sinus. There is still limited published literature related to the frontal sinus patterns and age group done in this comprehensive manner.

This study includes the limitation of unidentified frontal sinus morphological distribution among minority races in Malaysia, such as Iban and Kadazan Dusun, which consist of 1.0 % population in Malaysia [21]. Future studies could be done to explore the frontal sinus pattern distribution specifically to all the minority races in Malaysia. Nevertheless, this study provided a novel insight into the frontal sinus patterns among its major races of the Malaysian population.

In conclusion, the study revealed that the distribution of frontal sinus morphology varies according to sex, race and age to some degree. As the frontal sinus morphology is population-specific and data specific to the Malaysian population is limited, this study helps to build a database of the frontal sinus morphology, thus enhancing the potential use of frontal sinus in forensic investigation and assisting neurosurgeons in surgical planning involving frontal bone among Malaysian.

ORCID

Nur Damia Iwani Zulkiflee:

<https://orcid.org/0000-0002-1420-5168>

Mansharan Kaur Chainchel Singh:

<https://orcid.org/0000-0003-4150-6959>

Aspalilah Alias: <https://orcid.org/0000-0002-8062-6446>

Helmi Mohd Hadi Pritam:

<https://orcid.org/0000-0002-3225-8327>

Eric Chung: <https://orcid.org/0000-0001-8141-4544>

Rani Sakaran: <https://orcid.org/0000-0001-7094-8751>

Nurul Hannim Zaidun:

<https://orcid.org/0000-0001-9798-7099>

Choy Ker Woon: <https://orcid.org/0000-0002-8432-9035>

Author Contributions

Conceptualization: CKW. Data acquisition: NDIZ, EC. Data analysis or interpretation: NDIZ, MKCS, AA, CKW. Drafting of the manuscript: NDIZ. Critical revision of the manuscript: NDIZ, MKCS, AA, HMHP, EC, RS, NHZ, CKW. Approval of the final version of the manuscript: all authors.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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growth%20rate%20of%20Citizens,to%2029.7%20million%20in%202020.&text=Overall%2C%20there%20were%20more%20males,and%2015.9%20million%20(females).