Biomedical Sciences and Clinical Medicine 2025;64(3):193-199.
doi: 10.12982/BSCM.2025.19
https://he01.tci-thaijo.org/index.php/CMMJ-MedCMJ/index

BSCM
Biomedical Sciences and Clinical Medicine

Original Article

Open Access

Sex Estimation Using Radiographic Films of the Frontal Sinuses in Thai Populations

Bandhit Ngamnusonkit and Vijarn Vachirawongsakorn

Department of Forensic Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

Correspondence:
Vijarn Vachirawongsakorn, MD, PhD, Department of Forensic Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Rd. Bangkoknoi, Bangkok 10700, Thailand.
E-mail: vijarn.vac@mahidol.ac.th

Received: January 27, 2025;
Revised: March 23, 2025;
Accepted: April 1, 2025

ABSTRACT

OBJECTIVE This study aims to determine the forensic importance and applicability of the frontal sinus by evaluating its morphoscopic and morphometric characteristics in relation to sex.

METHODS Antero-posterior skull radiographs of 235 individuals (141 males and 94 females) were taken using a standardized procedure. Frontal sinus morphology was observed and classified. Specific measurements (A to D) were conducted to estimate sex by developing logistic regression equations.

RESULTS Frontal sinus symmetry was detected in 58.7% of the individuals. Morphometric analyses of frontal sinuses were only moderately correlated with the sex, with an area under the ROC curve of 0.629 (measurement A). The recommended cut-off score of measurement A was 6.47 cm, in which the sensitivity and specificity were 78.7% and 59.6%, respectively.

CONCLUSIONS This study found significant individual variation in the frontal sinus patterns. Evaluating the frontal sinus could be used as an adjunct to other methods of personal identification, particularly for sex estimation.

KEYWORDS frontal sinus, sex, forensic radiology, skull radiograph

INTRODUCTION

Human identification is a complex, systematic, and standardized process involving comparison of individual information about a missing person, including biological and personal information, with comparable data gathered from unknown human remains. Scientific techniques such as fingerprint analysis, DNA and dental matching, and anthropological methods are mentioned as common practices for personal identification (1, 2). To identify unknown deceased individuals, human identification is crucial in scenarios like mass disasters, accidents, and criminal investigations. Nevertheless, there are limitations of traditional identification methods like fingerprinting and DNA analysis, particularly when remains are decomposed, burnt, or when DNA is compromised. Anthropological techniques can be applied in these situations. Cranial radiography is one of the potentially useful identification techniques when only a portion of the skull may be available.

Examination using cranial radiography is recognized as a standard procedure in dental and medical clinics. To date, there have been many articles in which personal identification was achieved by comparing antemortem and postmortem radiographs of a particular part of a cranium (3-6). Using the frontal sinus became popular for human identification because of its unique characteristics. This structure consists of bilateral, irregularly shaped,

air-containing cavities in the frontal bone that can vary between individuals and can be visible with radiographic techniques (7). These factors make the frontal sinus suitable for analysis in an adult population (6, 7).

Sexual dimorphism is recognizable in several anatomical characteristics of the skull, such as the foramen magnum (8) and the mandible (9). Numerous studies have proposed that the frontal sinus could be helpful in accurately determining sex. Yoshino et al. suggested that the frontal sinuses of males are larger than those of females (6) which is in agreement with a study by Buckland-Wright (10). In females, the frontal sinuses are smaller, and their superior margins are more scalloped (11). A 2023 study of the frontal sinus in the Thai population by Pangsorn and Soodchuen (12) analyzed 270 cranial computed tomography (CT) images to evaluate sex determination based on the frontal sinus parameters. They proposed using parameters of frontal sinuses based on the following seven discrete variables: the absence or presence of frontal sinuses, scalloping, complete and incomplete septal lengths, max height and width, max total width, and max antero-posterior (AP) diameter. Their results showed that measurements of frontal sinuses (max height and width, max AP diameter, and total max width) have the potential to be used in correctly identifying sex. However, the question arises whether the results of CT examination can be compared with those based on radiographic examination. Plain x-ray investigation is still very important in routine forensic practice in Thailand because the method is readily accessible and cost-effective. To the best of our knowledge, no research has been done on determining sex from frontal sinus patterns in a Thai population using radiographic analysis. Because of variations in genetics and environment, the results from a non-Thai population may differ from those from the Thai population.

The purpose of this study was to evaluate the reliability of radiographic examination of the frontal sinus for sex estimation in a Thai population. The study analyzed the frontal sinus category and size using standardized measurements of plain X-rays of the frontal sinuses.

METHODS

Sample

This study was approved on October 20, 2023 by the Research Ethics Committee of the Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand (Protocol No. 716/2566 (IRB2).

The sample size was calculated using nQuery Sample Size Software (nQuery Advanced 8.7) (Statsols, Boston, MA). Between January 2019 and July 2024, adult cadavers which underwent autopsy in the Forensic Pathology Unit, Department of Forensic Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University were used as the subjects in this study. All cadavers were Thai nationals with an age range of 20-45 years.

It is generally accepted that the frontal sinus first appears in children as early as age 5 or 6. This structure becomes completely developed around the age of 20, and generally remains stable until advancing age when atrophic changes begin to appear (13-18). Deceased individuals with sinus pathologies such as mucosal thickenings or any masses in the sinuses were excluded from this study. In addition, individuals with a history of cranial trauma or surgery, a clinical history of endocrine disturbances, nutritional disorders, or hereditary facial asymmetries were excluded from the study. Subjects without an appearance of frontal sinuses were also excluded from this study.

Antero-posterior radiographs of skulls were taken with a mobile X-ray apparatus (SOURCE-RAY SR130, Source-Ray, Inc., NY) at 80 kvp, 3.0 mA, and a 0.1-minute exposure time. To ensure a symmetrical and clear image of the skull, the bodies were positioned with the chin slightly lifted, the back of the head against the image detector, and the central ray focused at the nasion. The examination of the radiographic images was carried out using RadiAnt DICOM Viewer software (version 2020.2.3 (32-bit)) (Fujidenolo Solutions Co., Ltd., Komaki City, Aichi, Japan) and a monitor.

Frontal sinus category and measurement protocol

The frontal sinus shape was classified according to the bilateral symmetry or asymmetry, the high point of each side, and the outline of upper borders (Figure 1 and Table 1). The shape of the frontal sinus was evaluated using the standardized measurement protocol adapted from De Andrade

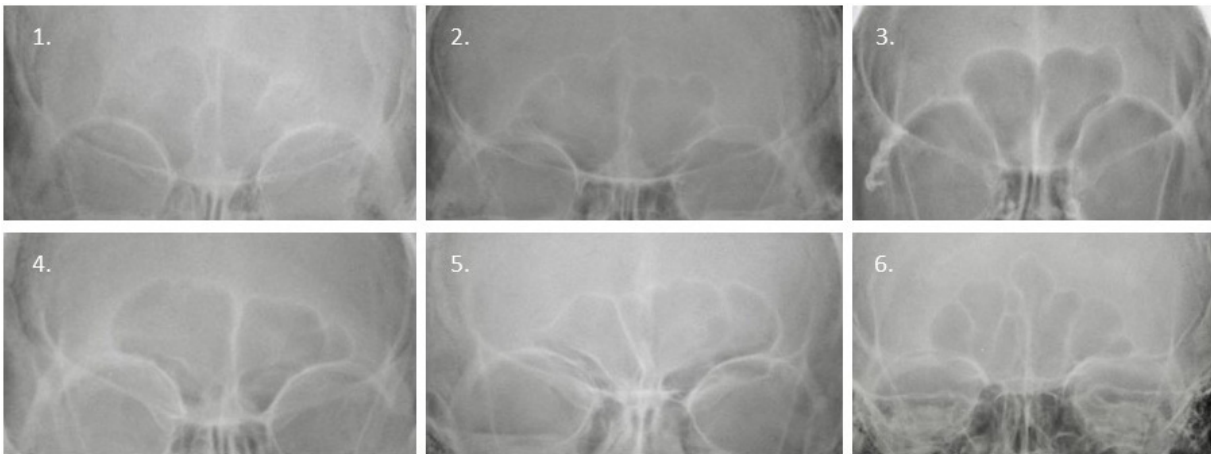

Figure 1. Frontal sinus (categories 1 to 6)

Table 1. Definition of frontal sinus categories

Category	Definition
1	Frontal sinuses with symmetrical shape of partition and chamber
2	Frontal sinuses with two equally high points
3	Frontal sinuses with open-curve lobulations (the highest curve is identified, but the highest point is difficult to determine)
4	Frontal sinuses with plateau lobulations (the highest point is not evident)
5	The air-containing cavity of the frontal bone as a part of the frontal sinus
6	Frontal sinuses in triangular shape without two distinct highest points because both sinuses coincide at the vertex of the triangle

Quintanilha Ribeiro (19). First, a baseline was drawn horizontally along the upper limit of both orbits. Then four more lines were drawn perpendicular to the baseline (Figure 2). The first (A) and second (B) lines delineate the maximum lateral limit of the right and left frontal sinuses. Another two lines (C and D) pass through the highest point of the right and left frontal sinuses. From these lines, the four measurements can be conducted (Table 2).

Anatomical variations can be encountered. Adapting the previously described techniques is necessary when measuring anatomy that does not fit a traditional architectural pattern (19).

1. When a frontal sinus has two equally high points, measure the one that is closest to the intersinus septum.
2. When the highest point is difficult to locate because the sinus has open-curve or plateau lobulation, measure the point at the middle of the lobulation.
3. Any air-filled frontal sinus cavity is considered as a part of the frontal sinus and needs to be measured.

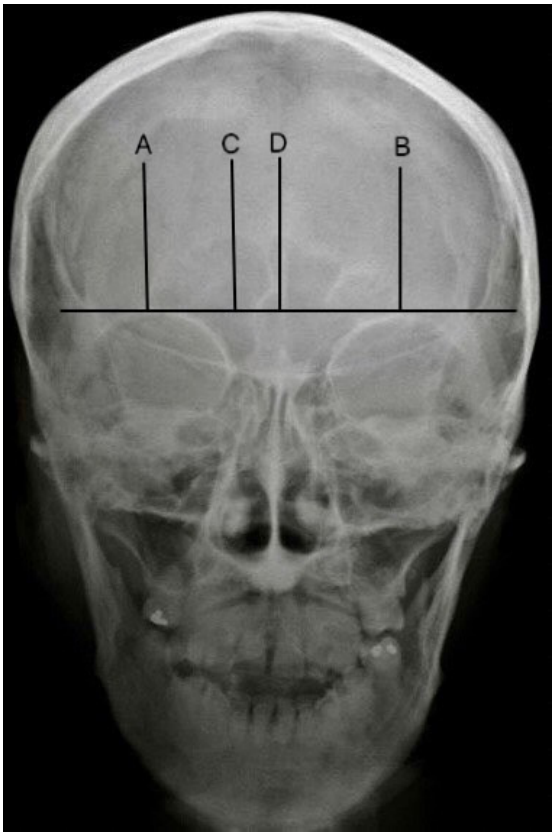

Figure 2. Landmarks for measurement protocol

Table 2. Measurement definitions (adapted from Ribeiro (19))

Measurement	Definition
A	The maximum diameter of the frontal sinuses (lines A and B)
B	The distance between the highest points of the left and right frontal sinuses (lines C and D)
C	The distance between the maximum lateral limit and the highest point of the left frontal sinus (lines A and C)
D	The distance between the maximum lateral limit and the highest point of the right frontal sinus (lines B and D)

4. In cases where the frontal sinuses do not have two separate highest points because of their triangular shape, the highest point of the vertex is used for measurement, and the list measurement of B is zero.

Statistical analysis

The statistical analysis was performed using the SPSS software package (version 26 for Windows; SPSS Inc., Chicago, IL). Statistical significance was considered as a *p*-value of less than 0.05. Quantitative data such as mean values, range, and standard deviations were calculated. Categorical data are displayed as numbers and a percentages. The t-test and chi-square test were performed to determine whether there was a significant difference between males and females. A logistic regression equation was used to analyze the association of measurement values and sex as ROC curves and the area under the curve. A cut-off score of the most significant statistical data was selected based on the sensitivity and specificity of the ROC curve. To test reliability, 30 skull radiographic images were randomly selected and reassessed for both intra- and inter-observer errors.

RESULTS

A total of 235 cadavers were included, consisting of 141 males and 94 females. The mean age of males and females in this study population was 35.25 (standard deviation [SD] = 7.01) years and 33.34 (SD = 7.35) years, respectively. The manner of death of the 235 subjects was as follows: 131 subjects (55.7%) were due to natural diseases, 55 subjects (23.4%) were due to car accidents, 39 subjects (16.6%) were due to suicide, and 10 subjects (4.3%) were homicides.

Table 3 illustrates the frequency of each type of frontal sinus category among the study group. The most common frontal sinus category observed in this study was category 1 (58.7%), followed by category 3 (18.7%), category 2 (6.8%), category 4 (6.4%), category 6 (6.0%), and category 5 (3.4%). However, there was a statistically insignificant sex difference in the frequencies of the frontal sinus category ($p = 0.226$).

Table 3. Frequency of frontal sinus category

Frontal sinus category	Male n=141 (%)	Female n=94 (%)	Total n=235 (%)
1	79 (56.0)	59 (62.8)	138 (58.7)
2	6 (4.3)	10 (10.6)	16 (6.8)
3	30 (21.3)	14 (14.9)	44 (18.7)
4	11 (7.8)	4 (4.3)	15 (6.4)
5	5 (3.5)	3 (4.3)	8 (3.4)
6	10 (7.1)	4 (4.3)	14 (6.0)

Table 4. Statistical data of frontal sinus measurements

Measurement	Sex	Mean (cm)	Standard deviation (cm)	*p*-value
A	Male	7.04	1.92	0.001*
	Female	6.21	1.65	
B	Male	2.04	1.17	0.990
	Female	2.01	1.11	
C	Male	2.37	1.20	0.019
	Female	2.00	1.09	
D	Male	2.68	1.13	0.002*
	Female	2.24	0.96	

* $p < 0.01$

The frequency of all frontal sinus measurements is shown in Table 4. The frontal sinuses were found to be larger in males than females, with the difference between males and females statistically significant for measurements A and D ($p < 0.01$). Univariable logistic analysis showed that the areas under the ROC curve in measurement A was 0.629 and 0.613 in measurement D, suggesting a moderate predictive performance. The recommended cut-off score of measurement A, which allows for the best sensitivity and specificity, is 6.47 (sensitivity 78.7%, specificity 59.6%).

The reliability of both morphoscopic and morphometric characteristics was also investigated. Using Cohen's Kappa coefficient, the average intra-class correlation coefficient (ICC) was 0.95 for intra-observer reliability and 0.91 for inter-observer reliability. Based on a 95% confidence interval, ICC values higher than 0.9 indicate excellent reliability (20).

DISCUSSION

Zukerkandl and colleague in 1895 were the first to notice the uniqueness of the frontal sinus, highlighting its asymmetrical morphology (21). Culbert and Law introduced the first case of human identification using morphological analysis of the frontal sinus to be accepted in a US court (22). Since then, there has been significant progress in the study of several frontal sinus features (1, 3, 12). Previous studies have concentrated on taking several frontal sinus measurements and integrating the probability of each measurement for analysis (19, 23). The strength of the metric analysis of the frontal sinus is supported by probability analysis of probability assessment (24). In accordance with previous studies, the present study used plain skull x-rays, and analyzed results using logistic regression.

Previous studies have looked at the frontal sinus using computed tomographic techniques (25-27). However, plain x-ray investigations continue to play an important role in routine forensic work for human identification in Thailand because of their reliability, low-cost, and easy accessibility, which has led to the development of technical and comprehensive parameters, e.g., the evaluation of the morphological shape of the frontal sinus (28, 29). Christensen (2005) employed elliptical Fourier analysis to compare Euclidian distances, but that method is very resource-intensive and complex (30). The present study attempted to develop a low-cost solution for the Thailand context, making it more appropriate for the financial constraints that are faced by disaster management organizations in Thailand. In addition, this study marks an initial attempt at personal identification based on standardized measurements of radiographic images of the frontal sinuses as mentioned by De Andrade Quintanilha Ribeiro and provides a simple and cost-effective system for identifying the sex of unknown remains (19).

The present study utilized plain skull x-rays in an AP radiograph projection, as this allows the frontal sinus to be assessed with minimal distortion. A difference in the position of the skull during radiographic examination can potentially generate differences in measurements, leading to possible misrepresentation of the true anatomical dimensions. The radiological images produced by AP and PA views are dissimilar in both size and clarity, even though the angles are similar. These two views provide different size measurements of the frontal sinus because the frontal sinuses are not located at the same distance from the film. In the AP view used in this study, the frontal sinus is farther away from the film, while the frontal sinus is closer to the film in the PA view, leading to a difference in magnification (31). In this study, it was often not possible to use the radiograph approach in PA projection due to the limitations resulting from position of the deceased lying in the supine position.

This study attempted to categorize different types of frontal sinus shapes to investigate how they could be used to determine sex and contribute to the field of forensic medicine. The radiological images of the frontal sinus revealed various forms in this study, differing in width, and height, as well as number and shape of partitions and chambers (31, 32). In this study, symmetry of the frontal sinus (category 1) was identified in 58.7% of the individuals, whereas Taniguchi et al. obtained 43.1% symmetry in a Japanese population (33). The results of the present study are consistent with those of David and Saxena (34), who observed a symmetry of frontal sinus in 58.0% of the study group. There can be several anatomical variations in size and shape. Unusual conditions can include asymmetrical sinuses or different shapes of lobulation. Generally speaking, an asymmetrical shape of the frontal sinuses on the two sides results from unequal reabsorption of the diploë during the development of the frontal sinus (35). Some studies have reported that the observed differences in frontal sinus morphology are not statistically significant. These differences can be ascribed to racial and geographic characteristics as well as to the different techniques used in each study (36).

Previous research has verified that males often have a larger frontal sinus than females (6, 7, 29, 31, 37). The results in this study are in accordance

with those of previous studies, including that the mean values of the frontal sinus measurements A and D in males are significantly larger than those of females, e.g., the same result was observed by Camargo et al. (28). This finding can be explained by the fact that males typically have larger skulls than females (38-40). The measurements B and C of males in the present study were larger than those of females, but the difference was not statistically significant. Inherent variability of the morphology of the frontal sinus was also observed in this study. We considered using a cut-off score with the best value to maximize both sensitivity and specificity. As a result, we recommend a cut-off score of 6.47, which provides moderate predictive accuracy in discriminating between males and females. There are possible reasons that the results of this study showed a lower accuracy than those of previous studies (25, 26, 28). The main reason is that the configuration of the frontal sinus in different populations is influenced by both genetics and environmental variables, e.g., nutrition, hormones, and muscular attachment (29, 31).

While CT scans generally provide higher resolution images, radiographic analysis of frontal sinus morphology is straightforward, lower cost, not time-consuming, and easy for a forensic practitioner to utilize. It can be done with a single radiograph, which is typically taken during postmortem investigation. However, some limitations of this study should be considered. Our study sample may not be representative of the general Thai population because this study included only forensic autopsy cases. A larger sample might provide better results. Newer frontal sinus parameters should also be established to determine sex more accurately.

CONCLUSIONS

In forensic practice, sex determination in unidentified individuals is one of the most frequent and challenging areas. Several methods have been established in an effort to increase the accuracy of the determination of sex. This study attempted to evaluate frontal sinuses as a means of determining sex based on sinus patterns and measurements. The method described here should encourage wider use of radiographic analysis of the frontal sinuses in sex determination.

ACKNOWLEDGEMENTS

We would like to thank Asst. Prof. Chulalak Komoltri for her support of the statistical tests. We would also like to acknowledge the anonymous reviewers for their helpful suggestions.

FUNDING

The authors received no financial support for the research, authorship, or publication of this article.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to report.

ADDITIONAL INFORMATION

Author contribution

B.N.: conceptualization, methodology, data collection, data analysis, writing - draft; V.V.: supervision, conceptualization, methodology, data analysis, writing – review and editing.

REFERENCES

1. Cameriere R, Scendoni R, Lin Z, Milani C, Palacio L, Turiello M, Ferrante L. Analysis of frontal sinuses for personal identification in a Chinese sample using a new code number. J Forensic Sci. 2020;65:46–51.
2. Chantharawetchakun T, Vachirawongsakorn V. Age estimation in the Thai male population using epiphyseal union of the medial clavicle. Chiang Mai Med J. 2021;60:149-55.
3. Alves CP, Costa C, Michel-Crosato E, Biazevic M. Use of the frontal sinus to evaluate sexual dimorphism in a Brazilian sample. Forensic Imaging. 2023;33:200548.
4. Christoloukas N, Mitsea A, Rontogianni A, Angelopoulos C. Gender determination based on CBCT maxillary sinus analysis: a systematic review. Diagnostics. 2023;13:3536. PubMed PMID: 38066777
5. Wen H, Wu W, Fan F, Liao P, Chen H, Zhang Y, et al. Human identification performed with skull's sphenoid sinus based on deep learning. Int J Legal Med. 2022;136:1067–74.
6. Yoshino M, Miyasaka S, Sato H, Seta S. Classification system of frontal sinus patterns by radiography: Its application to identification of unknown skeletal remains. Forensic Sci Int. 1987;34:289–99.
7. Schuller A. A note on the identification of skulls by X-ray pictures of the frontal sinuses. Med J Aust. 1943; 1:554-6.
8. Tambawala S, Karjodkar F, Sansare K, Prakash N, Dora A. Sexual dimorphism of foramen magnum using Cone Beam Computed Tomography. J Forensic Leg Med. 2016;44:29–34.
9. Esfehani M, Ghasemi M, Katiraee A, Tofangchiha M, Alizadeh A, TaghaviDamghani F, et al. Forensic Gender

Determination by Using Mandibular Morphometric Indices an Iranian Population: A Panoramic Radiographic Cross-Sectional Study. J Imaging 2023;9:40. PubMed PMID: 36826959
10. Buckland-Wright J. A radiographic examination of frontal sinuses in early British populations. Man. 1970; 5: 512-7.
11. Krogman W, Iscan M. The human skeleton in forensic medicine, 2nd ed. Springfield, IL: Charles C. Thomas; 1986. p. 125-6.
12. Pangsorn A, Soodchuen S. A computed tomography assessment of frontal sinus for sex determination in the Thai population. J Med Health Sci. 2023;30:104-13.
13. Bilgin S, Kantarcı U, Duymus M, Yildirim C, Ercakmak B, Orman G, et al. Association between frontal sinus development and persistent metopic suture. Folia Morphol. 2013;72:306-10.
14. Haglund W. Remains identification by frontal sinus radiographs. J Forensic Sci. 1992;37:1207. PubMed PMID: 1285776
15. Harris A, Wood R, Nortje C, Thomas C. Gender and ethnic differences of the radiographic image of the frontal region. J Forensic Odontostomatol. 1987;5:51–7.
16. Marques J, Musse J, Gois B, Galvão L, Paranhos L. Cone-Beam computed tomography analysis of the frontal sinus in forensic investigation. Int J Morphol. 2014;32:660-5.
17. Nambiar P, Naidu M, Subramaniam K. Anatomical variability of the frontal sinuses and their application in forensic identification. Clin Anat. 1999;12:16–9.
18. Patil N, Karjodkar F, Sontakke S, Sansare K, Salvi R. Uniqueness of radiographic patterns of the frontal sinus for personal identification. Imaging Sci Dent. 2012;42:213–7.
19. Ribeiro F. Standardized measurements of radiographic films of the frontal sinuses: an aid to identifying unknown persons. Ear Nose Throat J. 2000;79:26-8, 30, 32-3.
20. Koo T, Li M. A guideline of selecting and reporting intra-class correlation coefficients for reliability research. J Chiropr Med. 2016;15:155-63.
21. Zukerkandl E, Lichtwitz L, Garnault P. vol 1., Anatomy of the frontal sinus. In: Normal and pathological anatomy of the nasal cavity. Paris: G Masson; 1895. p. 349-61.
22. Culbert Wl, Law FM. Identification by comparison of roentgenograms of nasal accessory sinuses and mastoid processes. JAMA. 1927;88:1634-6.
23. Kullman L, Eklund B, Grundin R. The value of the frontal sinus in identification of unknown persons. J Forensic Odontostomatol. 1990;8:3-10.
24. Chiba M, Terazawa K. Estimation of stature from somatometry of skull. Forensic Sci Int. 1998;97:87-92.
25. Akhlaghi M, Bakhtavar K, Moarefdoost J, Kamali A, Rafeifar S. Frontal sinus parameters in computed tomography and sex determination. Legal Medicine (Tokyo). 2016;19:22-7.
26. Rao K, Doppalapudi R, Al-Shammari N, Patil S, Vundavalli S, Alam M. Evaluation of frontal sinus index in establishing sex dimorphism using three-dimensional cone beam computed tomography in Northern Saudi Arabian population. J Forensic Sci Med. 2022;8:1-5.
27. Silva R, Picoli F, Botelho T, Resende R, Franco A. Forensic identification of decomposed human body through comparison between ante-mortem and post-mortem CT Images of Frontal Sinuses: Case report. Acta Stomatol Croat. 2017;51:227-31.
28. Camargo J, Daruge E, Prado F, Caria P, Alves M, Silva R, et al. The frontal sinus morphology in radiographs of Brazilian subjects: Its forensic importance. Braz J Morphol Sci. 2007;24:239-43.
29. Verma S, Mahima V, Patil K. Radiomorphometric analysis of frontal sinus for sex determination. J Forensic Dent Sci. 2014;6:177-82.
30. Christensen AM. Testing the reliability of frontal sinuses in positive identification. J Forensic Sci. 2005; 50:18-22.
31. Quatrehomme G, Fronty P, Sapanet M, Grévin G, Bailet P, Ollier A. Identification of frontal sinus pattern in forensic anthropology. Forensic Sci Int. 1996; 83:147-53.
32. Ubelaker D. Positive identification from the radiographic comparison of frontal sinus patterns. In: Rathbun T, Buikstra J, editors. Human Identification. Springfield, IL: Charles C. Thomas; 1984. p. 399-411.
33. Taniguchi M, Sakoda S, Kano T, Zhu B, Kamikodai Y, Fujita M, et al. Possible use of nasal septum and frontal sinus patterns to radiographic identification of unknown human remains. Osaka City Med J. 2003; 49:31-8.
34. David M, Saxena R. Use of frontal sinus and nasal septum patterns as an aid in personal identification: A digital radiographic pilot study. J Forensic Dent Sci. 2010;2:77-80.
35. Soman B, Sujatha G, Lingappa A. Morphometric evaluation of the frontal sinus in relation to age and gender in subjects residing in Davangere, Karnataka. J Forensic Dent Sci. 2016;8:57. PubMed PMID: 27051227
36. Danesh Sani S, Bavandi R, Esmaili M. Frontal sinus agenesis using computed tomography. J Craniof Surg. 2011;22:e48-51. PubMed PMID: 22134322
37. Pondé J, Andrade R, Via J, Metzger P, Teles A. Anatomical Variations of the frontal sinus. Int J Morphol. 2008;26:803-8.
38. Rooppakhun S, Surasith P, Vatanapatimakul N, Kaewprom Y, Sitthiseripratip K. Craniometric study of Thai skull based on three-dimensional computed tomography (CT) data. J Med Assoc Thai. 2010;93:90-8.
39. Ruenhunsa S, Vachirawongsakorn V. Cranial thickness in relation to age, gender and head circumference in Thai population. Chula Med J. 2022;66:337-42.
40. Sangvichien S, Boonkaew K, Chuncharunee A, Komoltri C, Piyawinitwong S, Wongsawat A, et al. Sex determination in Thai skulls by using craniometry: multiple logistic regression analysis. Siriraj Med J. 2007;59: 216-21.