Optimizing frontal sinus minitrephination: A computed tomography-based anatomical analysis for enhanced surgical precision

Frontal sinüs minitrepanasyonunun optimizasyonu: Cerrahi hassasiyeti artırmaya yönelik bilgisayarlı tomografi tabanlı anatomik analiz

Abstract

Aim: Surgical management of chronic frontal sinusitis poses significant challenges due to the highly variable anatomy of the frontal sinus. While endoscopic sinus surgery (ESS) is commonly employed, it has limitations in accurately diagnosing and excising frontal sinus pathology, particularly in visualizing drainage pathways. Minitrephination serves as a less invasive alternative; however, anatomical variation often complicates the identification of a reliable entry point. This study aims to determine optimal anatomical landmarks for frontal sinus minitrephination using three-dimensional computed tomography (CT) imaging, with the goal of improving surgical accuracy and safety.

Methods: A total of 432 patients (864 frontal sinuses) were evaluated using 64-slice multidetector CT (MDCT) scanning. Frontal sinus dimensions and maximum depth were measured relative to predefined X and Y axes on axial, coronal, and sagittal images. Anatomical variations, including hypoplasia, were also recorded.

Results: Hypoplastic frontal sinuses were identified in 4.4% of right and 3.5% of left sinuses. The average depth of the frontal sinus was 14.43 ± 4.73 mm on the right and 14.48 ± 5.43 mm on the left. No significant correlation was found between sinus measurements and patient age. However, male patients exhibited significantly greater Y-coordinate values and frontal sinus depth compared to female patients ($p < 0.05$).

Conclusion: This study quantitatively demonstrates the extent of anatomical variation in the frontal sinus region and highlights sex-related differences. The findings support the implementation of precise CT-based preoperative planning for frontal sinus minitrephination. Such individualized anatomical mapping may reduce procedural complications and improve surgical outcomes in patients undergoing treatment for chronic frontal sinusitis.

Keywords: Anatomic variation; computed tomography; endoscopic surgical procedure; frontal sinus; paranasal sinus

Öz

Amaç: Kronik frontal sinüzitin cerrahi yönetimi, frontal sinüsün oldukça değişken anatomisi nedeniyle önemli zorluklar içermektedir. Endoskopik sinüs cerrahisi (ESC) yaygın olarak uygulanmakla birlikte, frontal sinüs patolojisinin doğru şekilde teşhisi ve eksizyonunda, özellikle de drenaj yollarının görselleştirilmesinde sınırlılıklar taşımaktadır. Minitrepanasyon, daha az invaziv bir alternatif olarak öne çıkmakta; ancak, anatomik varyasyonlar güvenilir bir giriş noktasının belirlenmesini güçleştirmektedir. Bu çalışma, üç boyutlu bilgisayarlı tomografi (BT) görüntüleme yöntemi kullanarak frontal sinüs minitrepanasyonu için optimal anatomik referans noktalarını belirlemeyi ve böylece cerrahi doğruluk ve güvenliği artırmayı amaçlamaktadır.

Yöntemler: Toplam 432 hastanın (864 frontal sinüs) 64 kesitli multidetektör BT (MDCT) görüntüleri değerlendirildi. Frontal sinüs boyutları ve maksimum derinlik, aksiyel, koronal ve sagital düzlemlerde tanımlanmış X ve Y eksenlerine göre ölçüldü. Hipoplazi gibi anatomik varyasyonlar da kaydedildi.

Bulgular: Sağ frontal sinüslerin %4,4'ünde ve sol frontal sinüslerin %3,5'inde hipoplazi saptandı. Frontal sinüsün ortalama derinliği sağ tarafta 14,43 ± 4,73 mm, sol tarafta ise 14,48 ± 5,43 mm olarak ölçüldü. Sinüs ölçümleri ile hasta yaşı arasında anlamlı bir korelasyon bulunmadı. Bununla birlikte, erkek hastalarda kadın hastalara kıyasla Y-koordinat değerleri ve frontal sinüs derinliği anlamlı olarak daha yüksek bulundu ($p < 0,05$).

Sonuçlar: Bu çalışma, frontal sinüs bölgesindeki anatomik varyasyonun nicel düzeyde belirginliğini ortaya koymakta ve cinsiyete bağlı farklara dikkat çekmektedir. Bulgular, frontal sinüs minitrepanasyonu öncesi hassas BT tabanlı planlamanın uygulanmasını desteklemektedir. Bu şekilde yapılacak bireyselleştirilmiş anatomik haritalama, işlem sırasında oluşabilecek komplikasyonları azaltabilir ve kronik frontal sinüzit tedavisi gören hastalarda cerrahi başarıyı artırabilir.

Anahtar Sözcükler: Anatomik varyasyon; bilgisayarlı tomografi; endoskopik cerrahi işlem; frontal sinüs; paranasal sinüs

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INTRODUCTION

Frontal sinusitis is a common inflammatory condition of the paranasal sinuses and remains a significant clinical challenge due to the complex and highly variable anatomy of the frontal sinus (1). Frontal sinusitis may present acutely or evolve into a chronic form, which is frequently associated with persistent headache, facial pain, and nasal discharge—symptoms that considerably impair patients' quality of life (2). Chronic frontal sinusitis is often compounded by anatomical anomalies, mucosal remodeling from previous surgical interventions, and long-standing inflammation, all of which can obstruct adequate drainage of the sinus cavity (3).

Endoscopic sinus surgery (ESS) is widely accepted as the first-line surgical treatment for chronic frontal sinusitis. It provides a minimally invasive approach to restoring sinus ventilation by enlarging the natural ostia to facilitate drainage (4). However, ESS has several limitations, particularly in the frontal recess. The frontal recess is frequently narrow, anatomically variable, and often contains postoperative scarring or inflammatory polyps, which impair visualization and surgical access (5). These factors contribute to incomplete drainage, persistent disease, and higher recurrence rates.

To address these challenges, frontal sinus minitrephination has gained attention as a complementary or alternative technique. This method involves creating a small, precisely positioned external fenestration into the frontal sinus, providing direct access for irrigation and instrumentation without disrupting the delicate architecture of the frontal recess (6). Minitrephination is particularly useful in revision cases where scarring and anatomical distortion limit the feasibility of conventional endoscopic techniques. Despite its increasing use, the literature lacks consensus on optimal entry points for minitrephination, and recommendations are largely based on anecdotal surgical experience rather than standardized anatomical data (7). Additionally, although intraoperative navigation systems are beneficial, they are not universally available, particularly in resource-limited settings.

The frontal sinus displays considerable anatomical variability not only between individuals but also between the left and right sides of the same patient. This variability complicates the identification of a safe and effective entry point for minitrephination. Prior surgical history, chronic inflammation, and polypoid disease further obscure surgical landmarks (8). While the challenges of frontal sinus access are well documented, few studies have systematically investigated the anatomical reference points necessary for consistent and safe minitrephination. As a result, current practice may carry increased risks of complications such as hemorrhage, damage to surrounding structures, or incomplete drainage (9).

Recent advances in imaging technology—particularly high-resolution three-dimensional computed tomography (3D-CT)—have enhanced our ability to visualize the detailed anatomy of the frontal sinus in axial, coronal, and sagittal planes (10). These capabilities are invaluable for preoperative planning, especially in revision or anatomically complex cases. Nevertheless, a limited number of studies have applied 3D-CT analysis to define ideal anatomical coordinates for frontal sinus minitrephination. Most existing literature provides generalized descriptions, lacking quantitative guidance for precise surgical planning (11).

To address this gap, the present study utilizes 3D-CT imaging to identify optimal anatomical landmarks for frontal sinus minitrephination. A total of 432 patients (864 sinuses) were evaluated through volumetric rendering using the Siemens Syngo Via workstation. Serial measurements were performed across three imaging planes to determine the deepest accessible points in the frontal sinus cavity.

The primary objective is to enhance surgical precision, safety, and clinical outcomes in patients undergoing minitrephination for chronic frontal sinusitis.

MATERIAL AND METHOD

Study design and setting

This study was approved by the Ethics Committee of İstanbul Medipol University in accordance with the Declaration of Helsinki, with the approval number (date 21.05.2019, decision no: 10840098-604.01.01-16117). This retrospective study was conducted at İstanbul Medipol University between 2020 and 2023. A total of 432 adult patients who underwent paranasal sinus computed tomography (CT) were included. The study population consisted of 158 females (35.3%) and 274 males (64.7%), with an age range of 18 to 77 years (mean age: 35.33 ± 10.70 years). The primary objective was to identify the optimal anatomical entry point for frontal sinus minitrephination through detailed morphometric analysis using three-dimensional CT imaging.

Inclusion and exclusion criteria

Patients aged 18 years and above with high-quality paranasal sinus CT scans were eligible for inclusion. Exclusion criteria included a history of significant facial trauma or prior extensive craniofacial surgery that could alter normal frontal sinus anatomy, as well as suboptimal CT image quality that would hinder accurate measurements. This selection ensured accurate evaluation of native frontal sinus morphology by eliminating confounding structural alterations.

Imaging protocol

All patients were imaged using a 64-slice multidetector CT (MDCT) scanner (Somatom Definition AS; Siemens Healthcare, Erlangen, Germany). A standardized protocol was applied: field of view (FOV) of 14–16 cm, 1 mm slice thickness, and axial acquisition from the hard palate to the superior margin of the frontal sinus. Following the acquisition, coronal and sagittal reconstructions were performed using the Siemens syngo Via workstation. High-resolution 3D reconstructions enabled a comprehensive assessment of frontal sinus anatomy for surgical planning (Figure 1).

Image analysis

CT scans were independently evaluated by two board-certified radiologists with subspecialty training in head and neck imaging. Evaluations focused on identifying the deepest point of each frontal sinus and its spatial orientation relative to standardized anatomical coordinates. In cases of discrepancy, consensus was reached through collaborative review to ensure inter-observer reliability (Figure 2).

Using volumetric rendering techniques, the deepest point of each frontal sinus was identified on coronal sections. Distances from this point to the X and Y axes were calculated to define the optimal location for minitrephination. This method allowed consistent and reproducible grading of anatomical deviation and provided practical landmarks for surgical entry (Figure 3).

Statistical analysis

All statistical analyses were performed using NCSS 2007 and PASS 2008 software (Number Cruncher Statistical System, Kaysville, Utah, USA). Descriptive statistics were calculated for demographic and anatomical variables. Group comparisons for parametric continuous data were performed using the independent samples t-test, while the Mann–Whitney U test was used for non-parametric variables. Pearson's correlation coefficient or Spearman's rank correlation coefficient was applied to assess associations between variables, depending on data distribution. A p-value of < 0.05 was considered statistically significant, while $p < 0.01$ indicated a highly significant association.

RESULTS

Hypoplastic frontal sinuses were observed in 4.4% of right-sided cases (n = 19), while 95.6% (n = 413) of the right sinuses exhibited normal pneumatization. The depth of the right frontal sinus in non-hypoplastic cases ranged from 6.5 mm to 37 mm, with a mean depth of 14.43 ± 4.73 mm. On the left side, hypoplasia was identified in 3.5% of cases (n = 15), whereas 96.5% (n = 417) displayed normal development. The depth of the left frontal sinus ranged from 2.0 mm to 30.8 mm, with a mean of 14.48 ± 5.43 mm (Table 1).

The X-axis measurements of the right frontal sinus ranged from 1 mm to 37 mm, with an average value of 15.70 ± 7.50 mm. For the left sinus, X-axis values ranged from 3 mm to 33 mm, with a mean of 15.20 ± 6.87 mm. Regarding Y-axis coordinates, right frontal sinuses measured between 1 mm and 14 mm, with a mean of 4.71 ± 1.86 mm. The corresponding Y-axis values for the left sinus ranged from 1.7 mm to 12 mm, with an average of 4.86 ± 1.72 mm (Table 2).

Septal deviation was not observed in 16.7% of the cases (n = 74). Right-sided deviation was present in 46.3% (n = 199), and left-sided deviation in 37.0% (n = 159). A maxillary septum was noted in 18.1% (n = 78) of patients, while 81.9% (n = 354) lacked this structure (Table 3).

Correlation analyses revealed no statistically significant relationship between age and X coordinate measurements for either sinus ($p > 0.05$). Similarly, there were no significant differences in Y-axis values between male and female subjects on either side ($p > 0.05$).

Table 1. Distribution of right and left depth measurement

		n	%
Right side	Hypoplasic sinus (+)	19	4.4
	Hypoplasic sinus (-)	413	95.6
	Depth	6.5-37.0	l4.43±4.73
Left side	Hipoplasic sinus (+)	15	3.5
	Hypoplasic sinus (-)	417	96. 5
	Depth	2.0-30.8	14.48±5.43

n: Number, %: Percent

Table 2. X and Y coordinate measurement

		Min - Max	Mean ± SD
X coordinate	Right sinus	1.0-37.0	15.70 ± 7.5
	Left sinus	3.0-33.0	15.2 ± 6.87
Y coordinate	Right sinus	1.0-14.0	4.71 ± 1.86
	Left sinus	1.7-12.0	4.86 ± 1.72

n: Number, SD: Standard deviation, min: Minimum, max: Maximum, %: Percent

Table 3. Distribution of septal deviation and maxillary septal observation rates

Characteristic	Frequency	Percentage
No septal deviation	74	16.7
Right septal deviation	199	46.3
Left septal deviation	159	37.0
Maxillary septal presence	78	18.1

Table 4. Evaluation of X and Y coordinate measurements by gender

		Gender		p value
		Female Mean±SD (Med)	**Male** Mean±SD (Med)	
X coordinate	Right sinus	15.52±7.46 (15.5)	15.93±7.53 (15.0)	0.774
	Left sinus	I5.00±7.20 (15.0)	15.31±6.70 (14.0)	0.658
	Total	15.26±7.32 (l5.0)	15.62±7.l3 (14.0)	0.605
Y coordinate	Right sinus	4.62±1.88 (4.2)	4.76±1.85 (4.50)	0.351
	Left sinus	4.60±1.64 (4.4)	5.01±1.75 (4.8)	**0.035***
	Total	4.61±1.76 (4.3)	4.89+1.80 (4.7)	**0.010***

SD: Standard deviation, med: Median, *Mann Whitney U Test, *p<0.05

Table 5. Evaluation of depth measurements by gender

Gender	Right sinus depth (Mean±SD)	Left sinus depth (Mean±SD)	Total sinus depth (Mean±SD)	p-value
Female	12.40±4.16	12.29±4.94	12.34±4.56	<0.001*
Male	15.54±4.66	15.65±5.33	15.50±5.00	<0.001*

SD: Standard deviation, *Mann Whitney U Test, p<0.05

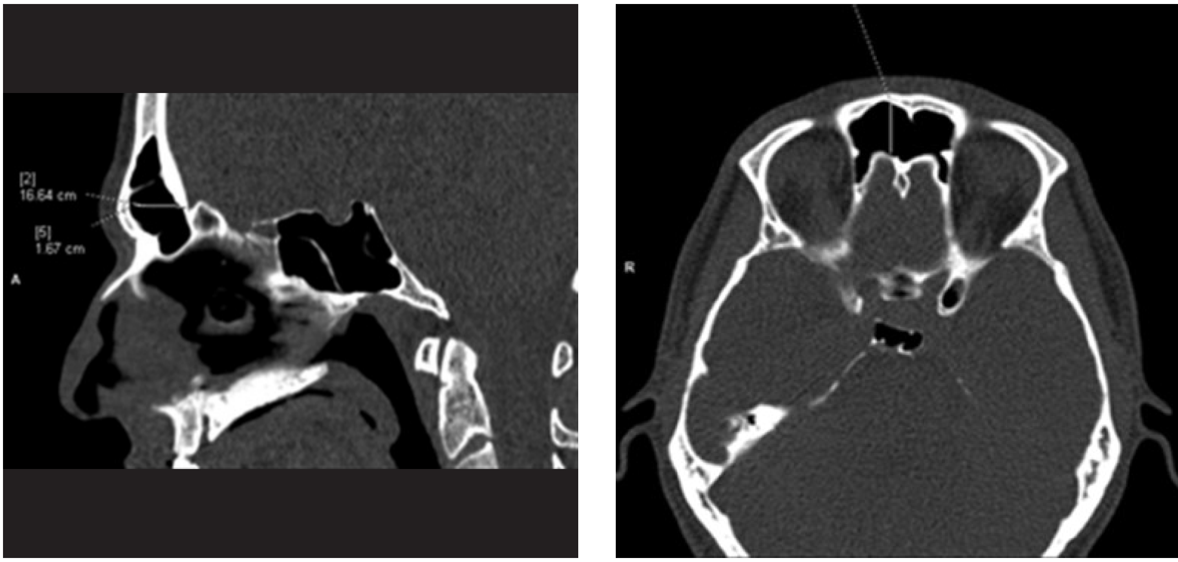

Figure 1a, 1b. Coronal and axial computed tomography sections showing anatomical landmarks used for frontal sinus measurements.

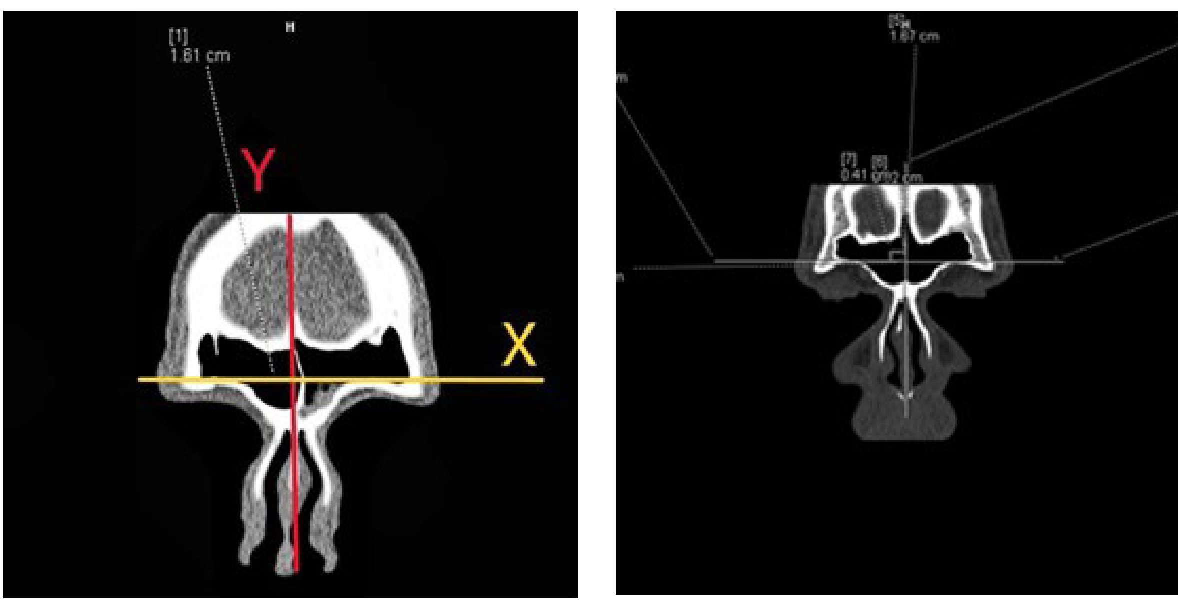

Figure 2a, 2b. Coordinate-based measurement system for frontal sinus localization. The X-axis connects the superior orbital rims (coronal view), and the Y-axis is perpendicular to the X-axis through the frontal bone midline. Axial and sagittal computed tomography sections illustrate linear distances from the nasion and midline to sinus walls (blue lines) and depth to the sinus floor (red line).

The comparative analysis of frontal sinus coordinate measurements between male and female subjects revealed no statistically significant differences in X-axis values for the right, left, or total sinuses. The mean X coordinate for the right sinus was 15.52 ± 7.46 mm in females and 15.93 ± 7.53 mm in males ($p = 0.774$). Similarly, the left sinus X coordinate averaged 15.00 ± 7.20 mm in females and 15.31 ± 6.70 mm in males ($p = 0.658$). The total X coordinate values showed no significant difference between the two groups (15.26 ± 7.32 mm in females vs. 15.62 ± 7.13 mm in males; $p = 0.605$).

However, Y-axis measurements demonstrated statistically significant differences. While the right sinus Y coordinate did not differ significantly between females (4.62 ± 1.88 mm) and males (4.76 ± 1.85 mm;

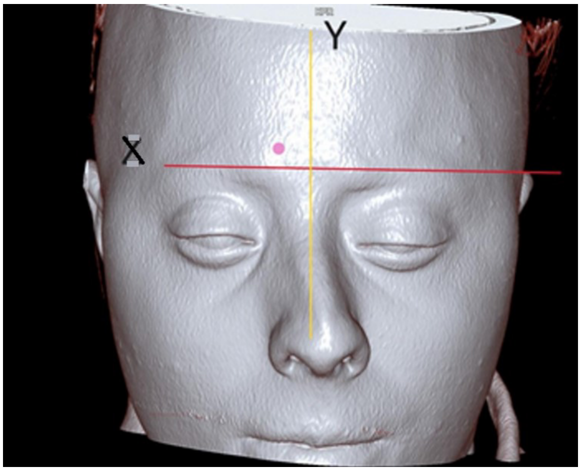

Figure 3. Three-dimensional composite reconstruction integrating coronal and axial computed tomography images to identify the ideal minitrephination site.

$p = 0.351$), the left sinus Y coordinate was significantly higher in males (5.01 ± 1.75 mm) compared to females (4.60 ± 1.64 mm; $p = 0.035$). The total Y coordinate was also significantly greater in males (4.89 ± 1.80 mm) than in females (4.61 ± 1.76 mm; $p = 0.010$). These findings suggest that gender-related anatomical variation may play a role in determining optimal minitrephination sites, particularly along the Y-axis (Table 4).

A statistically significant difference was observed in frontal sinus depth measurements between male and female patients. The mean total sinus depth in male subjects was significantly greater (15.50 ± 5.00 mm) compared to female subjects (12.34 ± 4.56 mm), with a p-value of <0.001, indicating strong statistical significance. This difference was consistently noted in both the right and left frontal sinuses. Specifically, males had a mean right sinus depth of 15.54 ± 4.66 mm and a left sinus depth of 15.65 ± 5.33 mm, while females demonstrated shallower measurements (right: 12.40 ± 4.16 mm; left: 12.29 ± 4.94 mm) (Table 5).

DISCUSSION

Despite advancements in surgical instrumentation and visualization techniques, the management of chronic frontal sinusitis remains a significant challenge in rhinologic practice (4). While the advent of endoscopic sinus surgery (ESS) has greatly facilitated minimally invasive approaches, anatomical variability in the frontal sinus continues to limit surgical access and increase the risk of complications (3). The highly variable structure of the frontal recess, its proximity to critical anatomical landmarks such as the orbit and anterior cranial fossa, and the risk of postoperative scarring all contribute to suboptimal surgical outcomes, especially in revision cases (11).

In this context, frontal sinus minitrephination has re-emerged as a valuable adjunct or alternative to ESS. This technique, which allows direct access to the frontal sinus via a small external opening, has been shown to enhance sinus drainage, facilitate culture-directed therapy, and provide effective irrigation—particularly in cases with distorted anatomy (7). Our findings support the utility of this approach and demonstrate that precise preoperative mapping using CT imaging is instrumental in identifying safe and effective entry points.

The results of this study are consistent with the literature in demonstrating substantial inter-individual and intra-individual variability in frontal sinus morphology (9). For example, we observed a 4.4% rate of hypoplastic sinuses on the right and 3.5% on the left, comparable to previously reported ranges (2–5%) (6). Moreover, our data revealed that male patients had significantly greater sinus depths and Y-coordinate values than females—a finding that mirrors the sex-based anatomical differences noted in earlier morphometric studies (10,11). However, in contrast to some prior studies, we did not observe a statistically significant correlation between age and any morphometric parameter, suggesting that sinus pneumatization stabilizes in early adulthood and is relatively unaffected by age thereafter.

The localization of the trephination site remains critical to avoiding complications. The orbital rim and the anterior skull base, including the cribriform plate, present high-risk zones for surgical error. As emphasized in the literature, inadvertent injury to the posterior sinus wall can result in cerebrospinal fluid (CSF) leaks or orbital complications (12,13). Our study reinforces the importance of CT-based preoperative planning, particularly the use of X and Y coordinate mapping, in minimizing these risks. This approach provides a reproducible and individualized method of site selection, which is not universally adopted in current surgical practice.

Furthermore, our results support previous recommendations that the surgeon must avoid violating the supraorbital and supratrochlear neurovascular bundles during entry. The palpation of the supraorbital notch, along with preoperative imaging, can significantly reduce the likelihood of iatrogenic nerve injury (14). Our CT-based technique offers additional confirmation of this anatomical landmark and enhances safety.

In contrast with older trephination techniques that relied on fixed surface anatomical landmarks, our method benefits from dynamic 3D imaging and individual anatomical assessment. This aligns with the evolving consensus that image-guided surgery, although resource-intensive, improves precision and patient outcomes (15-17).

In summary, our findings not only confirm previous observations regarding frontal sinus variability but also extend the literature by providing a systematic, reproducible method for defining optimal trephination coordinates using CT-based morphometry. The incorporation of such objective planning strategies into clinical protocols may help reduce complications, improve drainage success, and ultimately enhance outcomes in patients undergoing frontal sinus intervention.

Study limitations

This study has several limitations. First, the absence of intraoperative validation of the proposed trephination coordinates limits our ability to confirm their real-time surgical applicability and impact on clinical outcomes. Second, although detailed morphometric analysis was performed using high-resolution CT imaging, the lack of integration with surgical navigation systems or endoscopic findings may reduce translational accuracy in operative settings. Third, the study focused exclusively on adult patients; thus, the results may not be generalizable to pediatric populations, in whom frontal sinus development and pneumatization are not yet complete. Lastly, while inter-observer consensus minimized variability, the use of manual measurements instead of automated software introduces potential for human error. Future prospective studies incorporating intraoperative correlation, long-term patient outcomes, and pediatric cohorts are essential to further validate and expand upon these findings.

CONCLUSION

This study underscores the substantial anatomical variability of the frontal sinus and highlights the critical importance of individualized preoperative evaluation for planning minitrephination procedures. Among the 864 frontal sinuses analyzed, hypoplasia was observed in 4.4% of right and 3.5% of left sinuses. Although the mean sinus depth did not differ significantly between sides, notable variation was found in the X and Y coordinates, reflecting the challenges in identifying a standardized entry point.

The consistent localization of the frontal sinus floor and the anterior-posterior extension of the sinus relative to the nasion and midline provide valuable morphometric data for surgical planning. These measurements support the accurate preoperative identification of safe trephination sites, particularly in cases with limited endoscopic access or complex anatomical variations. Incorporating such detailed radiologic assessments into surgical planning can help avoid injury to adjacent structures and improve the precision of frontal sinusotomy or rescue trephination procedures.

While no significant sex-based differences were noted in X-axis values, males demonstrated significantly greater Y-axis measurements on the left and in overall evaluations. These findings suggest that sex-related anatomical differences may influence optimal access points. Additionally, the high prevalence of septal deviation (over 80%) further highlights the need for a customized surgical approach, as deviations can alter access trajectories and increase procedural difficulty.

In conclusion, a uniform approach to frontal sinus minitrephination is not practical. Instead, detailed three-dimensional computed tomography (CT) analysis should be used to determine patient-specific coordinates for safe and effective access. This strategy enhances surgical accuracy, minimizes complications, and improves outcomes in the treatment of chronic frontal sinusitis.

Conflict-of-interest and financial disclosure

The authors declare that they have no conflict of interest to disclose. The authors also declare that they did not receive any financial support for the study.

REFERENCES

1. Acharya S, Dash A. Frontal sinus and its outflow tract: a comprehensive anatomical and surgical review. Int J Health Sci. 2022;6(S8):6352–60.
2. Ansari H, Haghighi S. Headache or facial pain attributed to disorder of the cranium, eyes, ears, nose, sinuses, teeth, mouth, or other facial structure. In: Headache and Migraine in Practice. Academic Press; 2022. p. 187–200.
3. Davraj K, Yadav M, Chappity P, et al. Nasal physiology and sinusitis. In: Essentials of Rhinology. 2021. p. 49–101.
4. Craig JR, Saibene AM, Felisati G. Sinusitis management in odontogenic sinusitis. Otolaryngol Clin North Am. 2024;57(6):1157–71.
5. Hom DB, Bernstein JD. Reducing risks of facial scarring. Facial Plast Surg Clin North Am. 2023;31(2):195.
6. Verma H, Manchanda S, Kumar S, et al. Endoscopic anatomy and surgery. In: Essentials of Rhinology. 2021. p. 1–30.
7. Omani MA, Crepy-Ameil M, Grinholtz-Haddad J, Zaer S, Benkhatar H. Development of a new device for postoperative self-irrigation of the maxillary and frontal sinus. Ear Nose Throat J. 2023;102(4):239–43.
8. Yan CH, Kennedy DW. Evolution and challenges in frontal sinus surgery. In: Frontal Sinus Surgery: A Systematic Approach. 2019. p. 1–10.
9. Tawfik A, Abd El-Fattah AM, El-Sisi H, Kamal E, Ebada HA. Nasal spine of the frontal bone: a consistent landmark for safe outside-in frontal drill-out. Am J Rhinol Allergy. 2022;36(6):773–9.
10. Robles M, Morgan RM, Rando C. A novel method for producing 3D models of paranasal sinuses for forensic anthropology applications. Aust J Forensic Sci. 2021;53(6):693–702.
11. Cvrček J, Velemínský P, Jor T, Rmoutilová R, Brůžek J. Frontal sinus anatomy of the noble Swéerts-Sporck family and verification of their biological relationships using similarity analysis. Anat Rec (Hoboken). 2021;304(8):1717–31.
12. Patel RG, Chern A, Tan BK, Citardi MJ. Anatomic variations of the frontal sinus outflow tract: a computed tomography study of 1000 sides. Int Forum Allergy Rhinol. 2022;12(5):678–84.
13. Harvey RJ, Adappa ND. Navigating the frontal sinus: tools and techniques in the era of image guidance. Curr Opin Otolaryngol Head Neck Surg. 2021;29(1):34–40.
14. Douglas RG, Wormald PJ. Anatomical and pathophysiological aspects of frontal sinus surgery. J Laryngol Otol. 2020;134(S1):S8–14.
15. Yoon YH, Kim CH, Cho HJ. Analysis of frontal sinus measurements using three-dimensional computed tomography for surgical safety. Clin Exp Otorhinolaryngol. 2021;14(2):173–80.
16. Sedaghat AR, Gray ST. The role of image guidance in frontal sinus surgery: efficacy and safety review. Am J Rhinol Allergy. 2020;34(2):222–8.
17. Casiano RR. Contemporary approaches to the frontal sinus: from Draf I to Draf III and beyond. Oper Tech Otolaryngol Head Neck Surg. 2023;34(2):101205.