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Evaluation of posterior superior alveolar artery anatomy in patients with unilateral maxillary sinus hypoplasia using cone-beam computed tomography

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Abstract

The purpose of this study was to evaluate the posterior superior alveolar artery (PSAA) in individuals with unilateral maxillary sinus hypoplasia (MSH) using cone-beam computed tomography (CBCT), and to compare the anatomical features of the PSAA in hypoplastic and normal sides. A retrospective evaluation was performed on CBCT images from 101 patients with unilateral MSH. The visibility and anatomical location of the PSAA were recorded on both sides. Paired morphometric and PSAA type comparisons were restricted to 97 patients in whom the PSAA was visualized bilaterally. PSAA diameter, alveolar ridge height, and the distances from the PSAA to the alveolar crest, medial sinus wall, and sinus floor were measured and compared between the hypoplastic and normal sides. The PSAA was observed in 97.0% of hypoplastic sides and 98.0% of normal sides. Morphometric analysis was performed in 97 patients with bilateral PSAA visualization. The hypoplastic side showed greater alveolar ridge height and a greater PSAA–alveolar crest distance than the normal side ($p < 0.001$). In contrast, the PSAA was located closer to the medial sinus wall on the hypoplastic side ($p < 0.001$). PSAA diameter and PSAA–sinus floor distance did not differ significantly between sides. Type B was the most common location of PSAA bilaterally, without any significant difference in the distribution of types. Unilateral MSH is related to changes in the spatial relationship between the PSAA and the surrounding anatomical structures, especially the alveolar crest and medial sinus wall. These anatomical differences should be considered during CBCT-based planning of surgical procedures in the posterior maxilla.

Keywords: Maxillary sinus hypoplasia; posterior superior alveolar artery; cone-beam computed tomography

Introduction

The maxillary sinus begins to develop at approximately 14 to 16 weeks of gestation from the middle nasal meatus. As it develops, it extends toward the floor of the nasal cavity, alveolar process, zygomatic bone, and infraorbital wall [1,2]. It continues to grow after the eruption of the maxillary teeth, particularly in a caudal direction, and usually reaches adult dimensions by 15–18 years of age [2]. Differences in the size and shape of the maxillary sinus may exist between the two sides [1]. Maxillary sinus hypoplasia (MSH) refers to underdevelopment of the maxillary sinus. It may have a developmental origin or may be related to trauma or iatrogenic procedures [3,4].

The prevalence of MSH has been reported to range from approximately 1.5% to 10%, although some studies have reported lower frequencies [5,6]. Unilateral involvement appears to be more common than bilateral MSH [1,7,8]. Headache, facial pain, or nasal obstruction may occur in some patients [9,10]. However, MSH is often asymptomatic and may be detected incidentally on imaging performed for unrelated reasons [10]. Although MSH may influence sinonasal anatomy, no significant association has been demonstrated with dentoalveolar features such as maxillary occlusal cant, open bite, or mandibular asymmetry [11].

The main blood supply of the maxillary sinus is derived from branches of the maxillary artery, primarily the posterior superior

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alveolar artery (PSAA) and the infraorbital artery [12]. Their intra- and extraosseous branches form an anastomotic vascular network around the sinus [13]. The PSAA is clinically relevant because it is susceptible to injury during surgical procedures involving the maxillary sinus. Previous studies have therefore investigated its visibility, diameter, course, and relationship with the alveolar crest [12,14-17]. The PSAA is most commonly located within the lateral sinus wall or beneath the sinus membrane, whereas its location on the external cortical surface of the lateral wall is less common [18]. In some radiographic images, the artery may not be detected because of its relatively small diameter or its proximity to the inner or outer surface of the lateral wall, which may prevent the formation of a clearly visible bony groove [18].

Cone-beam computed tomography (CBCT) allows a three-dimensional (3D) examination of the anatomical structures relevant to maxillary sinus surgery [3]. It enables assessment of maxillary sinus morphology and anatomical variations, as well as the location of the PSAA. This information may be useful for surgical planning and may help reduce potential complications [19].

To our knowledge, the PSAA has not been specifically evaluated in patients with unilateral MSH. Thus, the aim of the present study was to evaluate the prevalence, location, and morphometric features of the PSAA on CBCT images in patients with unilateral MSH and to compare the hypoplastic side with the normal side.

Material and Methods

This retrospective study was performed under the Declaration of Helsinki. The data of the study were only accessible to the researchers involved in the study. The İnönü University Health Sciences Non-Interventional Clinical Research Ethics Committee (Approval No: 2026/10892, Date: 11.08.2026) granted ethical permission.

This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Study Design and Sample Selection

CBCT examinations performed for various clinical indications, including implant planning, impacted teeth, orthognathic surgery, maxillofacial lesions, and temporomandibular joint disorders, were retrospectively assessed using the radiological archive of the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Inonu University. A total of 2789 CBCT examinations of patients aged ≥ 18 years acquired from November 2024 through June 2026 were screened. Following application of the predefined eligibility criteria, 928 examinations were excluded, and the remaining 1861 examinations were assessed for the presence of unilateral MSH. A total of 101 patients with unilateral MSH were included in the study, as shown in the study flow chart (Figure 1). For paired morphometric and PSAA type comparisons between the hypoplastic and normal sides, analyses were restricted to patients in whom the PSAA could be identified bilaterally.

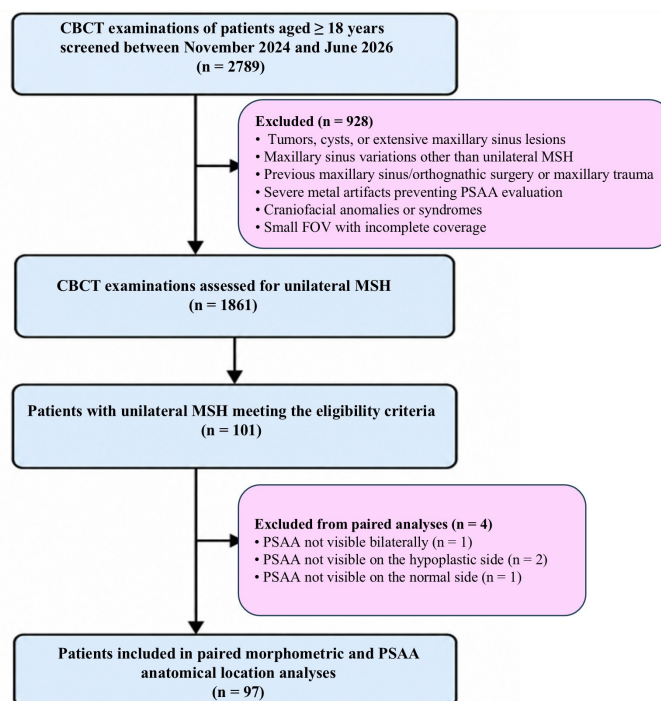


Figure 1. Flow chart of CBCT screening, patient selection, and inclusion in the paired analyses. CBCT: cone-beam computed tomography; FOV: field of view; MSH: maxillary sinus hypoplasia; PSAA: posterior superior alveolar artery.

Inclusion Criteria

- Presence of unilateral MSH
- Complete inclusion of both maxillary sinuses and the PSAA region within the field of view
- CBCT images of sufficient quality for diagnostic evaluation
- Age ≥ 18 years

Exclusion Criteria

- Presence of tumors, cysts, or extensive pathological lesions in the maxillary sinus region that could affect the evaluation
- Maxillary sinus variations other than unilateral MSH
- Previous surgery involving the maxillary sinus or orthognathic region, or a history of trauma affecting the maxilla
- Inability to evaluate the PSAA due to severe motion or metal artifacts
- Presence of craniofacial anomalies or syndromes

Imaging Protocol

All images in the archive were obtained using a NewTom 5G CBCT unit (QR S.r.l., Verona, Italy). Patients were scanned in the standard supine position using the following parameters: scan time, 18 s; exposure time, 3.6 s; field of view (FOV), 15×12 cm; tube voltage, 110 kVp; tube current, 1–20 mA; and voxel size, 0.3 mm^3 . During scanning the head was fixed inside the gantry with Frankfurt plane perpendicular to the floor and lips kept closed.

Identification of MSH

MSH was initially evaluated on coronal sections, with axial and sagittal sections used for confirmation through side-to-side comparison. Unilateral MSH was defined according to five radiographic features: (1) the sinus floor did not extend inferior to the nasal cavity floor; (2) the maxillary sinus was smaller and had a more oval configuration; (3) the orbit was larger and more oval in shape; (4) the medial sinus wall was positioned lateral to the medial orbital border; and (5) the lateral sinus wall was positioned medial to the orbital midpoint at the level of the infundibulum. The presence of at least four of these five features was required for classification as MSH [20] (Figure 2).

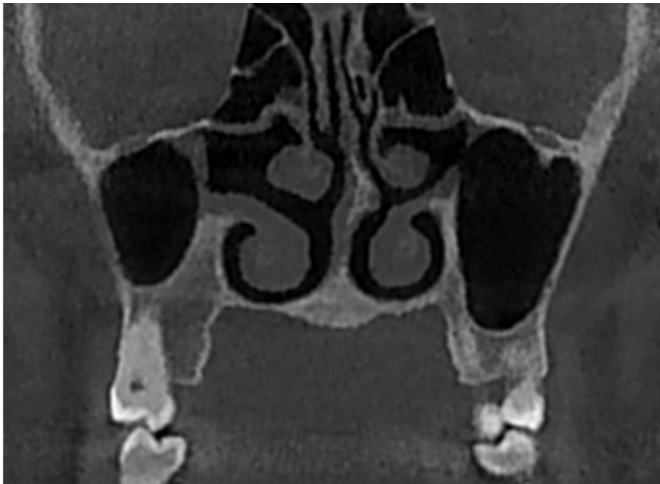


Figure 2. Coronal CBCT image showing unilateral maxillary sinus hypoplasia. Abbreviations: CBCT, cone-beam computed tomography.

PSAA Evaluation

The PSAA was traced on axial reconstructions from the second premolar to the second molar region. The coronal portion with the best visualization of the artery and the largest diameter was selected. The PSAA diameter and its distances from the

anatomical reference points were measured on this section [16]. On coronal sections, the distances from the PSAA to the alveolar crest, maxillary sinus floor, and medial sinus wall were measured, together with the alveolar ridge height (Figure 3). The anatomical position of the PSAA was classified as Type A, located beneath the Schneiderian membrane (submembranous); Type B, with an intraosseous course; or Type C, located on the outer cortex of the lateral sinus wall (extraosseous) (Figure 4).



Figure 3. On coronal CBCT sections, five anatomical measurements were obtained: (1) the distance from the alveolar crest to the PSAA, (2) alveolar ridge height, (3) the distance between the PSAA and the maxillary sinus floor, (4) the distance from the PSAA to the medial wall of the maxillary sinus, and (5) the diameter of the PSAA. Abbreviations: CBCT: cone-beam computed tomography; PSAA: posterior superior alveolar artery.

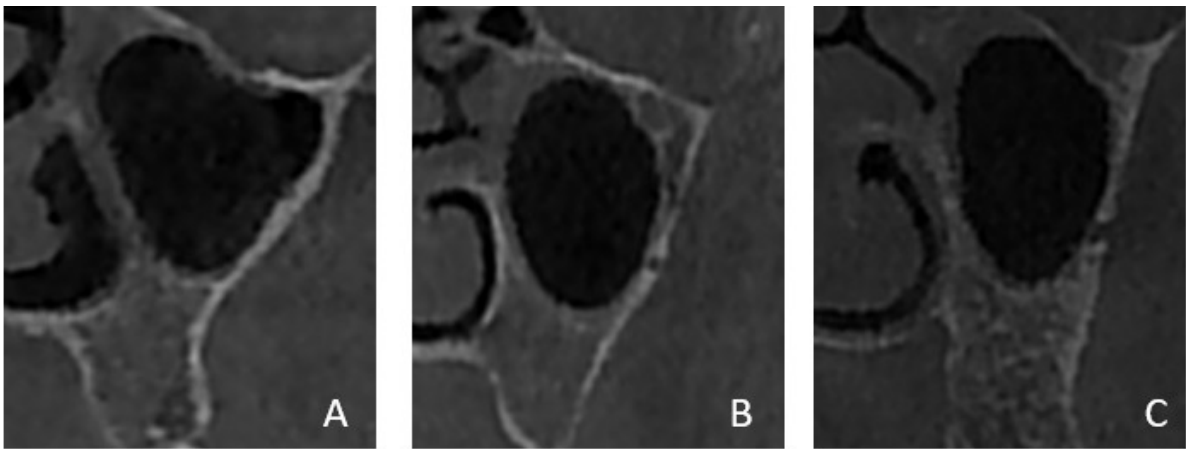


Figure 4. The PSAA was classified according to its anatomical position relative to the lateral wall of the maxillary sinus as (A) submembranous, (B) intraosseous and (C) extraosseous. Abbreviations: PSAA: posterior superior alveolar artery.

Image evaluation and linear measurements were carried out with NNT Viewer software (NewTom, QR Srl, Verona, Italy) by a radiologist specialized in oral and maxillofacial radiology with five years of experience. For the reproducibility analysis, the same observer repeated the assessment after two weeks using a randomly selected 30% of the images. Intraobserver agreement was calculated from these repeated assessments.

Statistical Analysis

Categorical variables were summarized as numbers (n) and percentages (%). Age was described using minimum–maximum, mean ± standard deviation, and median with interquartile range. Differences in age between females and males were examined with the Mann–Whitney U test, while the side distribution of MSH was analyzed using a two-sided exact binomial test. Paired-samples t-tests were applied to compare quantitative measurements between the hypoplastic and normal sides, with Cohen’s *d* used to estimate effect size. Differences in the marginal distribution of PSAA types were examined using the Stuart–Maxwell test, with the test statistic reported as χ^2 . Intraclass correlation coefficient (ICC) was used to assess intraobserver reliability of quantitative measurements and Cohen’s kappa for PSAA categorization. All analyses were two-sided and the level of statistical significance was set at $P<0.05$. Analyses were

performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY, USA), jamovi Version 2.4 (The jamovi project, Sydney, Australia), and R Version 4.5.1 (R Core Team; R Foundation for Statistical Computing, Vienna, Austria)

Results

Among the 101 patients evaluated, the PSAA was not visible bilaterally in one patient. It was not visible on the hypoplastic side in two patients and on the normal side in one patient. Overall, the PSAA was identified in 98 patients (97.0%) on the hypoplastic side and 99 patients (98.0%) on the normal side. Morphometric measurements were performed in 97 patients in whom the artery was visible bilaterally.

Among the 97 patients included in the paired analyses, 55 (56.7%) were female and 42 (43.3%) were male. Patient age ranged from 19 to 82 years, with an overall mean of 56.47 ± 19.31 years. Mean age was 54.05 ± 20.39 years among females and 59.64 ± 17.54 years among males, with no significant difference between sexes (Mann–Whitney U = 992.0; $p = 0.236$). MSH was present on the right side in 57 patients (58.8%) and on the left side in 40 patients (41.2%). No statistically significant difference was observed in the distribution between sides ($p = 0.104$) (Table 1).

Table 1. Demographic features of the participants and distribution of MSH

Variable	Gender		Overall	p value
	Female (n = 55)	Male (n = 42)	n = 97	
Age (years)				
Min – Max	19 – 82	19 – 82	19 – 82	
Mean ± SD	54.05 ± 20.39	59.64 ± 17.54	56.47 ± 19.31	0.236*
Variable	Side		Overall	p value
	Right	Left	Total	
Maxillary sinus status				
Normal	40 (41.2)	57 (58.8)	97 (100.0)	
Hypoplastic	57 (58.8)	40 (41.2)	97 (100.0)	0.104**

* Mann-Whitney U test; **Two-sided exact binomial test (test proportion = 0.50). Abbreviations: Min – Max, minimum – maximum; SD: standard deviation.

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Comparison of morphometric measurements between the normal and hypoplastic sides showed no significant difference in PSAA diameter, with mean values of 1.35 ± 0.48 mm and 1.31 ± 0.48 mm, respectively ($t(96) = 0.77$; $p = 0.443$; $d = 0.08$). In contrast, alveolar ridge height was significantly greater on the hypoplastic side, measuring 13.11 ± 4.95 mm on the normal side and 15.79 ± 4.72 mm on the hypoplastic side ($t(96) = -4.79$; $p < 0.001$; $d = -0.49$). A greater PSAA-to-alveolar crest distance was also observed on the hypoplastic side, with values of 17.96 ± 4.42 mm for the normal side and 20.88 ± 4.85 mm for the hypoplastic side ($t(96) = -6.70$; $p < 0.001$; $d = -0.68$). For the PSAA-to-maxillary sinus floor distance, the corresponding measurements were 5.58 ± 3.04 mm on the normal side and 5.83 ± 3.78 mm on

the hypoplastic side, with no significant difference between the two sides ($t(96) = -0.52$; $p = 0.602$; $d = -0.05$). Conversely, the PSAA-to-medial sinus wall distance was significantly greater on the normal side, measuring 10.33 ± 3.54 mm compared with 7.86 ± 2.74 mm on the hypoplastic side ($t(96) = 7.37$; $p < 0.001$; $d = 0.75$) (Table 2).

On the normal side, 12 arteries (12.4%) were classified as Type A, 57 (58.8%) as Type B, and 28 (28.9%) as Type C. On the hypoplastic side, 14 arteries (14.4%) were classified as Type A, 55 (56.7%) as Type B, and 28 (28.9%) as Type C. Type B was the most common on both sides. The distribution of PSAA types did not differ significantly between the normal and hypoplastic sides ($\chi^2(2) = 0.352$; $p = 0.839$) (Table 3).

Table 2. Comparison of morphometric measurements between the normal and hypoplastic sides

Measurement	Normal side	Hypoplastic side	t	p	Effect size (Cohen's d)
Artery diameter (mm)			0.77	0.443	0.08
Mean ± SD	1.35 ± 0.48	1.31 ± 0.48			
Median (IQR)	1.30 (1.00 – 1.60)	1.20 (1.10 – 1.50)			
Min – Max	0.50 – 2.70	0.40 – 3.00			
Alveolar ridge height (mm)			-4.79	< 0.001	-0.49
Mean ± SD	13.11 ± 4.95	15.79 ± 4.72			
Median (IQR)	13.20 (9.00 – 17.00)	16.50 (12.20 – 19.00)			
Min – Max	1.50 – 24.30	3.20 – 25.80			
PSAA to alveolar crest (mm)			-6.70	< 0.001	-0.68
Mean ± SD	17.96 ± 4.42	20.88 ± 4.85			
Median (IQR)	18.30 (15.60 – 21.00)	21.00 (18.80 – 23.40)			
Min–Max	8.70 – 27.60	5.60 – 34.50			
PSAA to sinus floor (mm)			-0.52	0.602	-0.05
Mean ± SD	5.58 ± 3.04	5.83 ± 3.78			
Median (IQR)	5.00 (3.60 – 7.50)	5.40 (3.00 – 7.10)			
Min – Max	0.30 – 16.50	0.60 – 19.50			
PSAA to medial wall (mm)			7.37	< 0.001	0.75
Mean ± SD	10.33 ± 3.54	7.86 ± 2.74			
Median (IQR)	10.30 (7.80 – 13.20)	7.80 (5.70 – 9.90)			
Min – Max	3.20 – 20.10	2.40 – 14.20			

p values were obtained using the paired-samples t-test; effect sizes are reported as Cohen's *d*. Abbreviations: Min – Max, minimum – maximum; IQR, interquartile range; PSAA, posterior superior alveolar artery; SD, standard deviation.

Table 3. Comparison of PSAA anatomical location between the normal and hypoplastic sides

PSAA type	Normal side, n (%)	Hypoplastic side, n (%)	χ ²	p
Type A	12 (12.4)	14 (14.4)		
Type B	57 (58.8)	55 (56.7)		
Type C	28 (28.9)	28 (28.9)		
Total	97 (100.0)	97 (100.0)	0.352	0.839

χ²: Stuart–Maxwell test statistic for marginal homogeneity. Abbreviations: PSAA: Posterior superior alveolar artery.

Discussion

The present study evaluated whether unilateral MSH is associated with alterations in the anatomical relationship of the PSAA with surrounding structures. The findings suggest that MSH is primarily associated with changes in the spatial relationship of the PSAA with the alveolar crest and medial sinus wall, whereas its diameter and relationship with the sinus floor appear to remain relatively unchanged. These findings suggest that the anatomical effects of MSH may extend beyond changes in sinus dimensions.

The PSAA was identified in 97.0% of the hypoplastic sides and 98.0% of the normal sides. These high detection rates are consistent with previous studies showing the effectiveness of CBCT in evaluating the PSAA. Özer et al. [19] identified the artery in all maxillary sinuses (100%), while other CBCT studies

in different populations reported detection rates above 97% and 98.3% [16,21]. In a few cases, the PSAA could not be identified. This may be related to an arterial diameter below the spatial resolution of CBCT or a non-intraosseous course. Previous studies have also noted that small vessels and vascular structures located beneath the Schneiderian membrane may not always be visible on CBCT images [16].

In patients with MSH, the nasal cavity may expand laterally over the alveolar ridge of the upper jaw; this causes the posterior teeth, which are normally attached to the floor of the maxillary sinus, to come into contact with the floor of the nose [7]. Posteroinferior extension of the nasal cavity, termed inferior meatus pneumatization, may reach the second molar region [22]. This anatomic variance may lower the available bone quantity in

the posterior maxilla and hence raise the risk of implant-related problems. Therefore, implants placed in this location without full CBCT assessment may lead to accidental oronasal perforation. In a previously reported case of MSH associated with periapical periodontitis of the maxillary first molar, resorption of the nasal floor and accompanying thickening of the adjacent nasal mucosa were observed [5]. In the present investigation, the PSAA was closer to the medial wall of the sinus on the hypoplastic side than on the normal side. Pandharbale et al. [23] reported a PSAA–medial wall distance of approximately 14–15.5 mm in the first and second molar regions. Although this distance has been studied in different anatomical locations in previous CBCT investigations [21], there is limited information directly comparing hypoplastic and normal maxillary sinuses. MSH has been associated with changes in the position of the medial and lateral sinus boundaries along with reduced sinus dimensions [9]. A recent systematic review and meta-analysis also showed that MSH may be accompanied by several sinonasal anatomical variations, emphasizing the morphological variability associated with this condition [4]. Therefore, the shorter PSAA–medial wall distance on the hypoplastic side may reflect altered transverse sinus morphology rather than an independent medial displacement of the artery.

Differences were also observed in the vertical anatomical relationships. Alveolar ridge height and the PSAA–alveolar crest distance were greater on the hypoplastic side. Previous studies have reported different values for the PSAA–alveolar crest distance. Jung et al. [24] reported distances of 18.92 mm in the premolar region and 14.79 mm in the molar region. Another study found values of approximately 17 mm in the molar regions [22]. A mean PSAA–alveolar crest distance of 22.09 mm was reported in another study, which attributed differences among studies to population characteristics, imaging protocols, and measurement methods [16].

The lack of a difference in the PSAA–sinus floor distance between the two sides suggests that the greater PSAA–alveolar crest distance may be related to altered sinus morphology associated with hypoplasia rather than vertical displacement of the artery relative to the sinus floor. Ilie et al. [7] noted that the maxillary sinus floor may be positioned more superiorly in MSH, increasing the distance between the antral floor and teeth roots. Aygun et al. [25] reported that vertical measurements of the PSAA may be influenced by the region evaluated, dental status, and measurement method. These findings support the possibility that MSH may affect vertical anatomical relationships in the posterior maxilla.

The course of the PSAA along the lateral sinus wall did not differ significantly between the hypoplastic and normal sides. On both sides, an intraosseous course was the most frequently observed location. This finding is consistent with the findings of Chitsazi et al. [26] and Yilmaz et al. [27], who found that the intraosseous course is the most common location of the PSAA. Alqhtani et al. [21] demonstrated that PSAA location may differ between the

premolar and molar regions. Thus, MSH may not alter the main course of the PSAA within the lateral wall but may affect its spatial relationship with the surrounding anatomical boundaries.

These anatomical relationships are particularly important for surgical procedures in the posterior maxilla. A recent review focusing on MSH in dental implant treatment emphasized the importance of recognizing these anatomical alterations during preoperative assessment and treatment planning [2]. Alsufyani et al. [9] reported changes in the position and angle of the maxillary sinus and the lateral nasal wall in MSH and stated that these changes should be taken into account prior to implant and sinus surgery. Damage to the PSAA may limit the surgical field of view, increase the risk of perforation of the Schneiderian membrane, and complicate graft placement [28]. Therefore, preoperative CBCT assessment in patients with MSH should not be limited to alveolar bone height. Individual evaluation of the PSAA course, diameter, and its relationship with surrounding anatomical structures may also be useful.

When interpreting the results of this study, certain limitations should be taken into account. The retrospective design and use of data from a single center may limit the generalizability of the findings to broader populations. The evaluation of the PSAA was based on CBCT images. Therefore, small vessels below the spatial resolution of the imaging system or vessels with a non-intraosseous course may not have been fully visualized. In addition, the location and morphometric measurements of the PSAA were assessed using predefined radiographic reference points. Anatomical variations along the entire course of the artery may therefore not have been reflected in the measurements. An important strength of this study is the within-subject comparison of the hypoplastic and normal sides, which reduced the effect of interindividual anatomical variability and allowed a more controlled assessment of morphological differences between the two sides.

Conclusion

This study shows that anatomical changes associated with MSH may affect the spatial relationship between the PSAA and neighboring structures. Changes in sinus morphology suggest that standard anatomical relationships in the posterior maxilla may not apply to every patient. Therefore, individual assessment of the PSAA and neighboring anatomical structures on CBCT images should be considered when planning implant and sinus surgery in patients with MSH.

Ethical Approval

The study was approved by the Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (Approval No: 2026/10892, Date: 11.08.2026) and was conducted in accordance with the Declaration of Helsinki. Patient anonymity and confidentiality were maintained throughout the study.

Patient Consent

Not applicable, as this study was retrospective and did not include any case reports or identifiable patient information.

Conflict of Interest

The authors confirm the absence of any conflicts associated with this work.

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