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Research article

Exploring the age and gender-based distribution of paranasal sinus osteomas using cone beam computed tomography: A retrospective cross-sectional study☆

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ABSTRACT

Objective: The objective of this study is to explore the prevalence, size, location and radiographic features of osteomas in the paranasal sinuses using cone beam computed tomography imaging.
Study design: This study was planned as retrospective cross-sectional. 499 consecutive cone beam computed tomography scans obtained in a dentomaxillofacial radiology department for various dental indications. Statistical analysis of all data was done with SPSS version 22. Descriptive statistics and chi-square tests were used to determine the prevalence of categorical parameters.
Results: Osteoma was detected in 7 % (n = 35) of the 499 images analyzed. The age of the patients ranged from 6 to 96 years (mean 42.03 ± 18.70). No significant difference was found between the genders ($p = 0.77$). In terms of localization, it was significantly more common in the ethmoid sinuses ($p < 0.01$). Cortical type osteoma was observed the most frequently in the analyzed images ($p < 0.01$). The incidence of osteoma was not significant depending on age ($p = 0.50$).
Conclusion: Osteomas in the paranasal sinuses show a 7 % prevalence in CBCT images, with the ethmoid sinus being the most common site. The average size of osteomas was 3.43 ± 1.78 mm, predominantly cortical in type. These findings highlight the necessity for thorough examination of CBCT images by dentomaxillofacial radiologists to avoid overlooking osteomas.

1. Introduction

Osteomas, typically benign and distinctly bordered, are bone-producing tumors with a mesenchymal origin and consist of mature bone tissue featuring a layered structure. Predominantly found as benign growths within the paranasal sinuses (PNS), osteomas are often located within the cranial bones, paranasal sinuses, and the mandible. The prevalence of PNS osteomas, as detected by standard radiography and computed tomography (CT) scans, ranges between 0.42 % and 3 % [1,2]. Although most frequently present in the frontal and ethmoid sinuses, they can also manifest in the sphenoid and maxillary sinuses [3]. These tumors can be identified at any stage of life but are most commonly detected from the ages of 40–60, with a higher incidence in males [4]. The female/male ratio ranges from 1:1.08 to 1:2.6 [3,5]. The origins of osteomas continue to be a topic of active debate, with theories suggesting embryologic, traumatic, or inflammatory initiations [6]. Boffano et al. reported that progressive headaches and persistent inflammation are often

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associated with these tumors, and headaches occur in 52 %–100 % of cases [7]. While PNS osteomas might not cause symptoms initially, they can lead to structural distortion or compression of neighboring tissues. Symptomatic cases typically arise from the obstruction of sinus drainage or encroachment upon nearby structures, with the signs varying based on the tumor's specific location, direction of growth, and size [8].

In CT and cone beam computed tomography (CBCT), they appear as dense, compact, homogeneous, round or oval-shaped and well-limited masses. Magnetic resonance imaging (MRI) is also valuable diagnostic tool, particularly for differentiating other conditions and for osteomas that have spread to the brain or orbit [7].

The management of PNS osteomas is subject to debate. In older patients with small, asymptomatic osteomas, routine monitoring with imaging methods may be sufficient. Surgical intervention is considered if the osteoma occupies more than half of the sinus, enlarges rapidly (>1 mm/year), extends into the cranium or orbit, or leads to sinusitis and mucocele by blocking the frontal recess [9–11]. Additionally, some experts advocate for the early removal of sphenoid osteomas due to the potential risks of compression on critical structures such as the optic nerve, the orbital apex, or the carotid artery [12].

To the best of our knowledge, there has been no research conducted to date that details the occurrence rates of osteomas in the paranasal sinuses with the use of CBCT imaging. Therefore, the objective of this research is to analyze the prevalence, size, location and radiological characteristics of osteomas within the paranasal sinuses, with a particular focus on variations across different ages and between genders, as captured through CBCT.

2. Materials and methods

2.1. Study design

The study protocol was submitted and approved by the clinical research ethics board of Akdeniz University Faculty of Medicine (2022,162), which complied with the Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study.

This retrospective study was carried out by examining cone beam computed tomography images taken for different dental indications such as implants, extraction of impacted teeth, and orthognathic surgeries in the Akdeniz University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology clinic, Antalya, Turkey. All CBCT images were acquired by the same X-ray technician and with the Veraview X800 (Morita, Kyoto, Japan). The scans were evaluated by the imaging software for three-dimensional (3D) images, i-Dixel 2.0 (J. Morita, Kyoto, Japan). Images were viewed using a Dell monitor (22″ Full HD 1920 × 1080 display) in a dimly lit room.

2.2. Data collection

Taking into consideration the 6.4 % prevalence of PNS osteomas reported in the study by Dong Hong Lee et al· [13], the sample size for this study was calculated using the sampling formula for a known population (with a 99.99 % confidence level and a 5 % margin of error). Consequently, CBCT images from 499 patients were included in this analysis.

499 CBCT images with paranasal sinuses in the imaging area, with adequate imaging quality and without motion and metallic artifacts were included in the study. The study excluded images that did not encompass the paranasal sinuses or those of inferior quality showing artifacts that precluded proper radiological assessment. Patients with a history of trauma, prior surgical procedures, cancerous growths, or widespread disease affecting sinonasal structures were also excluded. Additionally, the study did not consider indistinct calcifications and osteomas smaller than 3 mm that could not be clearly identified amid the surrounding opacity, noise, or sinus septa development. We classified PNS osteomas into three patterns according to the CBCT findings [14,15];

1. Compact (ivory, eburnated, cortical) osteoma: Osteomas composed predominantly of very dense bone with only small hypodense areas.
2. Spongy (mature, cancellous): Osteomas composed of dense bone with more hypodense areas.
3. Mixed: Tumors with both ivory and mature features.

In cases of uncertainty, the gray scale values within the i-Dixel 2.0 software (Morita, Kyoto, Japan) were quantitatively compared to determine whether the internal structure of the PNS was eburneous, cancellous, or mixed. Digital radiographic images were imported into the software, and a specific region of interest (ROI) was manually selected for each osteoma. The grayscale values, representing pixel intensity from 0 (black) to 255 (white), were extracted from the ROI. A histogram was generated to visualize the distribution of these values, and statistical metrics such as mean, median, mode, and standard deviation were calculated to quantify the grayscale distribution. This quantitative data facilitated the classification of osteomas based on their density, with higher mean grayscale values indicating hyperdense (eburneous/cortical) osteomas and lower values indicating hypodense (spongy) osteomas. By employing this method, the classification process was standardized, reducing subjectivity and enhancing the accuracy and reproducibility of the findings.

2.3. Statistical analysis

Statistical analysis of the presence of calcifications, distribution by age and gender and width and height measurement data of calcifications were performed using SPSS version 22. Basic descriptive statistical analyzes and normality tests of all variables were performed. Normality assumption was evaluated using the Shapiro-Wilk method. Categorical data were evaluated with the Chi-Square test. While numerical data were evaluated with the Student's *t*-test. Statistical significance level was accepted as $p < 0.05$.

All evaluations were investigated in the CBCT images of all the subjects by two oral and maxillofacial radiologists (Z.M.S., S.G.Y.). To ensure calibration and standardization between observers, 20 % of the images were selected randomly (100 patients) and assessed jointly, while the remaining images were evaluated independently. In cases of uncertainty, a third dentomaxillofacial radiologist with 12 years of experience was consulted. To minimize the margin of error for the evaluator, all measurements on the CBCT images were evaluated in the early hours of the day and in a dimly lit environment with no more than 20 patients per day.

3. Results

Interobserver agreement and intraobserver reliability values obtained as a result of Kappa for osteoma presence were perfect (0.915, 1.0 and 0.962, respectively). A total of 499 patients between the ages of 6 and 96 years were evaluated. The mean age of the whole group (min:6, max: 96) was 42.07 ± 18.70 years. Of the 499 people included in the study, 267 (53.5 %) were male and 232 (46.5 %) were female. A total of 35 osteomas were detected. The prevelance of PNS osteomas was determined to be 7 %. The mean age of the group with osteoma was 44,51 ± 19,87 years (min:10, max: 77). The mean age of the group without osteoma was 41,89 ± 18,63 years (min:6, max: 96) ($p = 0.41$). Of the cases with osteoma the incidence rate was 42,9 % in women and 57,1 % in men; the male:female ratio was found to be 1.1:1. The incidence between genders was not statistically significant ($p = 0.78$) (Table 1). The ethmoid sinus was the most commonly involved site with 19 cases (54.3 %). Ten tumors affected the sfenoid sinuses (28,6 %) and a further five the frontal sinuses (14.3 %). Also one maxillary sinus osteoma (2,9 %) was encountered.

We examined paranasal sinus osteomas in 3 types according to the classification of Arslan et al. and McHugh et al. [14,15]. The cortical type was the most common type of osteoma (62.9 %, n:22); This was followed by the spongy type (25,7 %, n:9) and the mixed type (11.4 %, n:4), respectively.

The size of the osteomas varied from approximately 1,15 to 7,58 mm. The average size was 3,43 ± 1,78 mm (Table 2).

According to the distribution as right-left direction: 16 osteomas were observed on the right side; 19 osteomas were observed on the left side. In patients with PNS osteoma, the accompanying pathologies and anatomical variations were evaluated based on the criteria established in the study by Janovic et al. [5]. In patients with PNS osteoma, the accompanying pathologies and anatomical variations were evaluated based on the criteria established in the study by Janovic et al. [5]. Among the 35 patients with PNS osteomas, the following anatomical variations were observed: supraorbital ethmoidal cells in 2 patients (5.71 %), sphenomaxillary plates in 6 patients (17.14 %), sphenoethmoid cell in 1 patient (2.86 %), pneumatization of the anterior clinoid process in 4 patients (11.43 %), concha bullosa in 10 patients (28.57 %), infraorbital ethmoid cells in 6 patients (17.14 %), pterygoid pneumatization in 11 patients (31.43 %), crista galli pneumatization in 5 patients (14.29 %), septum deviation in 10 patients (28.57 %), and septum pneumatization in 4 patients (11.43 %). No mucoceles were observed in any of the patients.

4. Discussion

Paranasal sinus osteomas are benign bony tumors that develop within the paranasal sinuses, which are air-filled cavities located in the skull [1]. These slow-growing, often asymptomatic tumors primarily consist of mature, compact bone tissue. While generally non-cancerous, paranasal sinus osteomas can vary in size and location within the sinuses, occasionally causing symptoms or complications [16].

Osteomas are relatively rare, and their etiology remains unclear. They are thought to arise from the proliferation of osteogenic cells within the sinus mucosa or periosteum. Although frequently discovered incidentally during imaging studies conducted for unrelated reasons, paranasal sinus osteomas may warrant attention when they lead to symptoms such as nasal obstruction, facial pain, or recurrent sinusitis [10]. Understanding the clinical characteristics, diagnostic modalities, and treatment options for paranasal sinus osteomas is crucial for healthcare professionals to effectively manage and counsel patients with this benign osseous pathology.

In a 1935 publication, T.E. Carmody noted the historical documentation of sinus osteomas within medical literature, although the precise timing of the initial case report remained uncertain [17]. In 1940, Wallace R. referred to Veiga's work, which is reputed to

Table 1
Demographic characteristics according to the presence of osteoma.

Variables	Osteoma			
	Missing (n = 464)	Valid (n = 35)	Total (n = 499)	p[a]
Gender, *n(%)*				0,786
Female	217(46,8)	15(42,9)	232(46,5)	
Male	247(53,2)	20(57,1)	267(53,5)	
Age (year)				0,413[b]
Mean±SD	41,89 ± 18,63	44,51 ± 19,87	42,07 ± 18,70	
Median(min-max)	42(6–96)	46(10–77)	42(6–96)	

[a] Pearson Ki square test, Yates correction.
[b] Mann Whitney *U* test.

Table 2
Clinical features of patients with osteoma.

Variables (n = 35)	Number (n)	Frequency (%)
Localization		
Frontal sinuses	5	14,3
Etmoid sinuses	19	54,3
Maxillary sinuses	1	2,9
Sphenoid sinuses	10	28,6
Type		
Cortical type	22	62,9
Spongy type	9	25,7
Mixed type	4	11,4
Side		
Right	16	45,7
Left	19	54,3
	Mean ± SD	**Median(min-max)**
Size (mm)	3,43 ± 1,78	2,81(1,15–7,82)

discuss the earliest known instance of a paranasal sinus osteoma dating back to the year 1506 [18]. Robert E. Priest referenced Sjoberg's findings that, as of 1927, there had been 277 documented cases of paranasal sinus osteomas. Childrey opined that while osteomas in the sinuses are uncommon, they are not exceedingly rare. He posited that the incidence of small osteomas might be higher than reported, as they often go unnoticed due to the absence of symptoms, and that most case reports tend to focus on larger tumors that affect nearby anatomical structures [19]. Hermann Knapp identified four instances of orbital osteomas that originated from the paranasal sinuses within a dataset of 56,000 cases. He observed that these tumors were more commonly located in the base of the frontal sinus compared to other areas within the paranasal sinuses [20].

The underlying causes of osteoma formation remain elusive, though theories involving developmental, traumatic, and infectious factors have been postulated. The occurrence of osteomas near the embryonic confluence of the cartilaginous ethmoid and the membranous frontal bones suggests a developmental origin. However, this embryological hypothesis falls short of explaining the numerous osteomas that arise away from the frontoethmoidal junction. There are occasional reports in medical literature of intracranial mucoceles appearing in conjunction with paranasal sinus osteomas. Typically, osteomas and mucoceles present separately within the paranasal sinuses. Nonetheless, it has been hypothesized that paranasal sinus osteomas may lead to the development of intracranial mucoceles by blocking the natural sinus drainage pathways [3,16,21]. Some scholars propose that the higher incidence of osteomas in the paranasal sinuses among males could be related to trauma, as per the traumatic theory. However, this does not account for the development of osteomas in those who have no trauma history. In the cohort studied, none of the participants reported any previous traumatic incidents. The infectious theory suggests that osteomas might originate from a sinus infection, and there are indeed studies that have found a correlation between the presence of paranasal sinus osteomas and sinusitis [1,2,5,22,23]. In this study, mucosal thickening was observed around the maxillary sinus osteomas in 2 of 35 patients with osteoma.

Osteomas of the paranasal sinuses tend to be asymptomatic unless they grow to a size that impairs adjacent tissues. The primary symptoms that manifest with PNS osteomas are pain and headaches, which are typically concentrated at the site of the osteoma. Additional symptoms can include facial asymmetry and swelling, discharge from the nose, blocked nasal passages, sinus infections, and orbital manifestations such as bulging eyes, excessive tearing, double vision, and loss of sight. Neurological manifestations may include vertigo, inflammation of the brain membranes, air-filled cysts within the cranial cavity, brain abscesses, and leakage of cerebrospinal fluid, among others [2,18,23]. In medical literature, tumors exceeding 30 mm are categorized as giant tumors. The size of these tumors typically ranges from 1.5 mm to 40 mm. It is hypothesized that tumor growth rates are highest during the adolescent years, which is a period of peak bone growth, although the rates of growth can differ from case to case. Within the context of our research, the most substantial osteoma measured was 24 mm [2,10,21]. In the study of Erdoğan et al. which involved the analysis of 1,889 CT images of the paranasal sinuses, the subjects under study were symptomatic, presenting with various sinus-related complaints [2]. None of the patients with PNS osteoma in our cohort presented with symptoms attributable to the osteoma; they sought care at our clinic for routine dental complaints and underwent CBCT for dental reasons such as implants, extraction of impacted teeth, and orthognathic surgeries. Consequently, no treatment was administered to patients with PNS osteoma. According to a comprehensive case series, the average annual growth rate of osteomas in the paranasal sinuses is approximately 1.61 mm, though instances of growth rates as high as 6.0 mm per year have been documented [24]. Despite PNS osteomas being slow-growing benign bone tumors, this study entailed the regular monitoring of patients with PNS osteomas at regular intervals. Currently, there are no definitive protocols for the intervals and frequency at which surveillance CT scans should be conducted. The recommendation for medical practitioners is to rely on their clinical assessment when determining the need for subsequent CT scans. More research is necessary to facilitate the development of standardized guidelines [25].

Aksakal et al. posited that osteoma patients often have more anatomical variations in their paranasal sinuses than those without osteomas. They found a correlation between PNS osteoma and various anatomical anomalies, including concha bullosa, secondary middle turbinate, and Haller's cell. The researchers proposed that such correlations may stem from both genetic and environmental influences [1]. Facial trauma during the period of bone maturation in adolescents has been postulated to disrupt bone remodeling processes, potentially contributing to osteoma formation. This hypothesis is further supported by the higher incidence of trauma observed in males [8]. Nonetheless, our findings indicate a slight dominance in men, although the incidence between genders was not statistically significant ($p = 0.78$). It is important to note that due to the absence of comprehensive data regarding the history of facial trauma in adolescence within our study, the impact of trauma on our results cannot be precisely determined [3]. The fact that osteomas are frequently seen in the fourth and fifth decades in the literature is consistent with this study [14,21].

The presence of multiple osteomas may point to Gardner Syndrome, a rare hereditary condition with autosomal dominant inheritance. Affected individuals may develop a range of conditions, including gastrointestinal polyps, osteomas, desmoid tumors, epidermoid cysts, fibromas, lipomas, and retinal abnormalities. Additionally, various dental and maxillofacial anomalies such as extra or impacted teeth, odontomas, and dentigerous cysts are reported in medical literature in association with this syndrome [26,27]. Patients with Gardner syndrome are acknowledged to have a heightened risk of developing colon cancer. Consequently, it is advised to conduct regular surveillance through lower gastrointestinal endoscopy to track the progression and potential malignant transformation of polyps. In cases where a patient has 20 or more polyps, prophylactic colectomy is generally recommended as a preventative measure against the onset of colon cancer [28]. In our study none of the patients had more than one osteoma.

It is well-established that CT scanning is the benchmark for diagnosing osteomas in the paranasal sinuses. However, the advent of CBCT imaging has revolutionized paranasal sinus imaging, offering a viable alternative to conventional CT for assessing odontogenic sinusitis and sinus anatomical variances. The affordability of CBCT equipment, coupled with the benefits of reduced radiation exposure and the ability to produce isotropic volumetric images over a wide field, while still delivering high-resolution images, has allowed newer CBCT machines to perform comprehensive evaluations of the paranasal sinuses. The effectiveness of CBCT imaging in distinguishing between air, mucosal tissue, and bone within the paranasal sinuses is exceptional, facilitating an in-depth examination of sinus anatomy and aeration, which has been corroborated by prior research [29,30]. CBCT devices provide isotropic voxel capability, which means the voxels have equal dimensions in all three spatial planes. This contrasts with the anisotropic voxels of conventional CT,

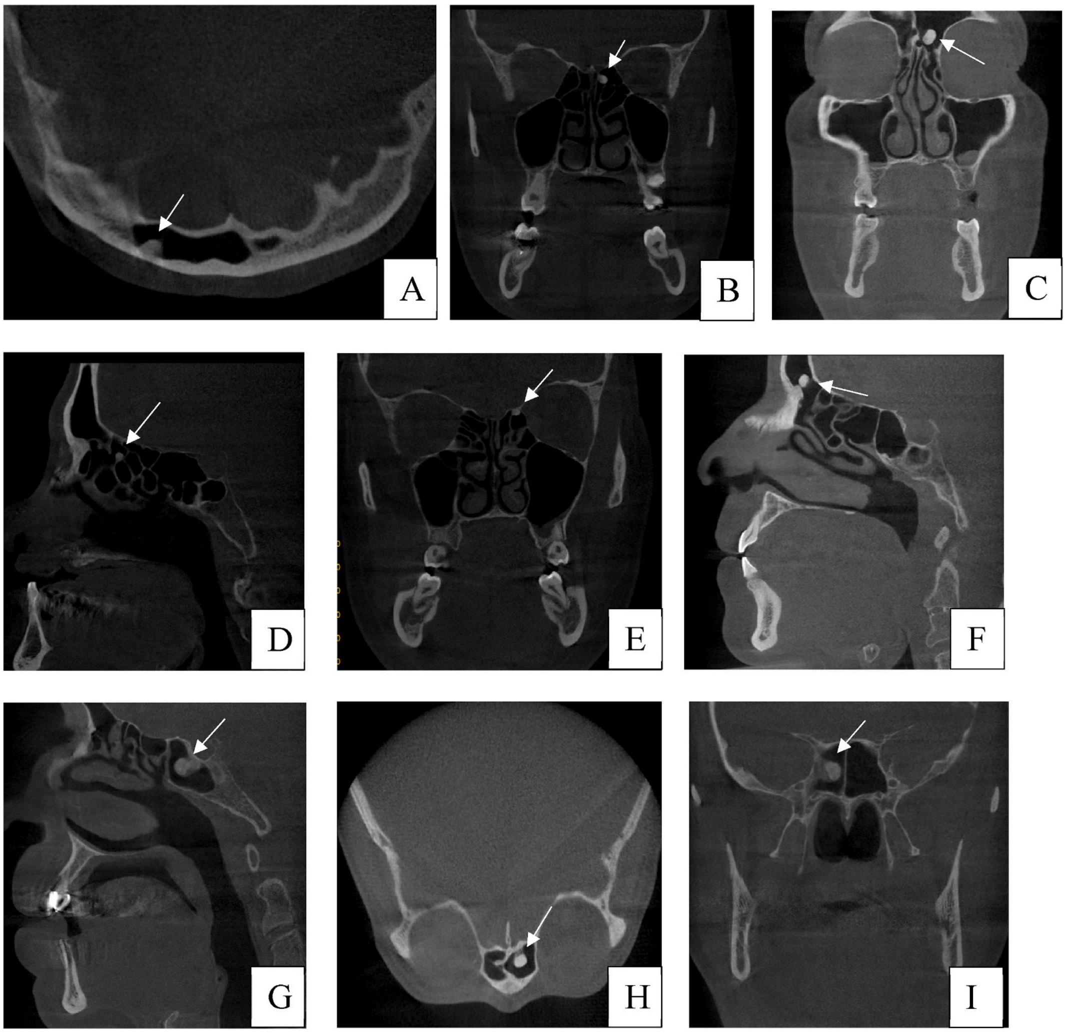

Fig. 1. (A–I): A: Axial scan shows mixed type lesion discovered incidentally in the frontal sinus. **B–F:** Coronal scans of osteomas in the anterior etmoid sinus. **G-I:** Sphenoid sinus osteomas in pedunculated and mixed structure.

where voxel dimensions can vary between the different planes. The isotropy in CBCT facilitates enhanced visualization of the bone structures of the head and neck in cross-sectional imaging [31]. Furthermore, CBCT provides a resolution of up to 0.09 mm, which enables high precision imaging [32]. Although the incidence of paranasal sinus osteoma is reported between 0.01 % and 0.23 % in earlier studies, this frequency varies from 1 to 3 % in recent studies [2,3,21]. This is associated with the advancements in imaging methods enabling to detect very-small size osteomas [33]. With the widespread use of advanced imaging methods in the imaging of the paranasal sinuses, the diagnosis and treatment of paranasal sinus osteomas has also improved. In our study, the prevalence of osteoma in the paranasal sinuses was 7 %. Our result is compatible with recent studies but can be considered slightly higher. This may be due to CBCT showing higher spatial resolution than CT in imaging of bony structures. In the study of Dong Hong Lee et al., the frequency of osteoma in the paranasal sinuses was 6.4 % [13]. According to Dong Hong Lee et al., the increased detection rate of abnormalities in their study could be attributed to the utilization of a thin-slice CT protocol. This approach differs markedly from the 3 mm slice thickness conventionally used in earlier research, with the slices in their CT study varying from 0.6 to 2 mm in thickness [5,21]. In the present study slice thickness values ranged from 0.5 to 1 mm in CBCT (Fig. 1). In this study, the highest incidence of osteoma was found in the ethmoid sinuses (54.28 %), in line with the studies of Çelenk et al. and Erdoğan et al. [2,10]. This was followed by sphenoid sinus (28.57 %) and frontal sinus (14.28 %). In addition, one maxillary sinus osteoma was found (2.85 %). However, in these studies, the frontal sinus was the second most common sinus with osteoma. Frontal sinus localization was reported as 75.3 % by Buyuklu et al. [3] and 59.3 % by Ref. [34] et al. The reasons why osteomas commonly occur in the frontoethmoidal area are not fully understood. One theory, based on embryology, suggests that these osteomas may develop from remnants of embryonic cartilage or from the embryonic periosteum that remains. Another theory proposes that injuries to the frontoethmoidal region could lead to an increase in the activity of bone-forming cells, contributing to osteoma formation [3,14].

Osteomas in the maxillary and sphenoid sinuses are uncommon. The use of imaging slices with a thickness of 0.5–1 mm significantly enhances the detection of lesions in the ethmoid sinus, greatly improving the identification of small osteomas in this area [25]. We posit that the employment of CBCT, a notable strength of our research, is highly efficacious in identifying even small osteomas within the ethmoid sinus.

One of the strengths of our study is the noteworthy prevalence of osteomas in asymptomatic patients who sought medical attention for various reasons and were assessed using imaging methods such as CBCT. This indicates that even asymptomatic paranasal sinus osteomas can be associated with various pathologies. Therefore, it is crucial for dentomaxillofacial radiologists to meticulously interprete all images for the presence of paranasal sinus osteomas.

Our study had some limitations. Initially, its retrospective nature meant that a thorough analysis of the clinical manifestations of osteomas was not feasible. Furthermore, like previous studies on the incidence of PNS osteomas, diagnoses were made based on radiological data. Although there was a chance that non-osteoma bone tumors could have been included, we assessed that their impact on the reported incidence of PNS osteomas was minimal, given osteomas' distinctive pedunculated radiological profile. Unlike earlier research, future studies employing CBCT, which delivers high-resolution imagery and superior visualization of the bony architecture of the sinonasal area, might reveal a greater prevalence of PNS osteomas, aligning with our findings.

To summarize, we conducted an exploratory study using CBCT scans of the paranasal sinuses to examine the prevalence, size, location and radiological characteristics of osteoma patients. While paranasal sinus osteomas are generally uncommon, asymptomatic, and benign growths that develop slowly, they can lead to serious complications due to their closeness to vital anatomical structures. It is essential for dentomaxillofacial radiologists to thoroughly evaluate all portions of the CBCT scans to ensure that no osteomas within the paranasal sinuses are overlooked during the diagnostic process. Our findings indicate a higher prevalence of PNS osteomas compared to other studies, which may be attributed to the imaging technique we utilized. Considering CBCT is recognized as the gold standard for bony tissue evaluation, we recommend clinicians to employ CBCT in uncertain cases to enhance diagnostic accuracy.

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Data availability statement

Data sharing is not applicable.

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Zeliha Merve Semerci: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Sevcihan Günen Yılmaz:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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