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Incidental maxillary sinus findings in orthodontic patients: a radiographic analysis using cone-beam computed tomography (CBCT)

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Structured Abstract

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Objectives – To determine the frequency of incidental maxillary sinus findings using cone-beam computed tomography (CBCT) images made for orthodontic purposes.

Setting and Sample Population – One hundred thirty-nine consecutive CBCTs from 134 patients treated at the Department of Orthodontics and Dentofacial Orthopedics, University of Bern, Bern, Switzerland. Indications for CBCT imaging included the localization of impacted teeth and root resorption related to impacted teeth.

Material and Methods Population – Two experienced observers reviewed the CBCT scans (fields of view: 4 × 4/6 × 6/8 × 8 cm) and recorded all incidental maxillary sinus findings according to standardized categories. The patient's age and gender, the size of the field of view, the season of CBCT image taking, and the thickness of the Schneiderian membrane were evaluated to identify potential influencing factors.

Results – In 65 CBCTs (46.8%), incidental maxillary sinus findings were found (interrater classification agreement of 95.7%/95% CI: 90.9–97.9%). Three types of incidental findings were diagnosed: flat mucosal thickening (23.7%), polypoid mucosal thickening (19.4%), and signs of acute sinusitis (3.6%). There was no correlation between the field of view of the CBCT and the number of incidental findings inside the field. There was no correlation between the season during which the CBCT was made and the number of incidental findings. The mean thickness of the mucosal lining in the maxillary sinus was 1.58 mm (95% CI: 1.17–1.98 mm).

Conclusions – A high percentage of the CBCTs made for orthodontic diagnostic purposes exhibit incidental maxillary sinus findings not associated with the primary indication.

Key words: cone-beam computed tomography; incidental finding; maxillary sinus; orthodontics; pathology

Introduction

Unlike conventional extraoral radiographs, cone-beam computed tomography (CBCT) provides essential three-dimensional information on dental and maxillofacial structures. When compared to computed

tomography (CT), CBCT's main advantage is a lower radiation dose administered to the patient (1, 2). This is especially important when treating children, because radiographs produced for orthodontic reasons potentially contribute significantly to the radiation burden in young adults (3). CBCT devices can exhibit significant variations in dose depending on the system, the field of view (FOV), the tube potential and the tube current (4, 5). By choosing the appropriate machine and smallest FOV for the specific indication, the ALARA (as low as reasonably achievable) principle can be satisfied, which is of significant importance when evaluating children.

The systematic use of CBCT imaging for diagnostic procedures and treatment planning in orthodontics is still not considered standard care (6). However, for some orthodontic diagnostic and treatment planning procedures, such as the localization of impacted teeth, assessment before orthognathic surgery of the mandible and maxilla, temporomandibular joint (TMJ) visualization, airway and soft tissue analysis, and evaluation of cleft palate, CBCT imaging is clearly beneficial (7–9).

In orthodontics, CBCT scans with a limited FOV are often performed in the maxilla – for example, for the localization of impacted teeth (9). However, only limited data are available regarding the frequency of incidental findings with CBCT imaging in the craniofacial region. One case report described the incidental discovery of a potentially life-threatening intracranial aneurysm in a CBCT performed for dental purposes (10). In another case report, mid-line clefts of the cervical vertebrae were diagnosed in a CBCT scan conducted for orthodontic purposes (11). A recent study evaluated incidental findings in 500 CBCT scans with a large FOV made for orthodontic, TMJ, endodontic, and implant indications. In this study, an overall rate of incidental findings of 24.6% was reported for the orthodontic group (12). Using magnetic resonance imaging (MRI) scans to analyze incidental paranasal mucosal changes, the highest prevalence was reported for the ethmoidal sinuses, followed by the maxillary sinuses (13, 14). The maxillary sinuses had a prevalence of shallow/flat mucosal thickening ranging from 23 to 31%, and a prevalence of cystic lesions ranging from 7 to 10% (14).

To the best of our knowledge, no study exists reporting about the characteristics of the Schneiderian membrane and the frequency of incidental pathological findings in the region of the maxillary sinus in CBCT scans with a limited FOV produced for orthodontic diagnostic purposes. Therefore, the primary goal of this study was to analyze the frequency and type of incidental findings in the maxillary sinus and to evaluate the dimensions of the Schneiderian membrane in limited CBCTs made for orthodontics in asymptomatic patients. Secondary outcome parameters were the analysis of a potential correlation between these findings and the age and gender of the patients, the FOV of the CBCT, and the season (winter/spring/summer/autumn) during which the radiography was performed.

Patients and methods

Patients

All CBCT scans produced for orthodontic diagnostic purposes from March 2006 to September 2008 at the School of Dental Medicine at the University of Bern were initially eligible for this study (n = 187). Only CBCT images made for adjuvant reasons to conventional two-dimensional radiographs for orthodontic indications were included. These indications were the following: the position and localization of impacted teeth and root resorption related to impacted teeth. Patients with a cleft palate (n = 8) were excluded from the study, as their maxillary sinus is usually altered. In addition, all CBCTs of poor quality, of the lower jaw only, or of the upper jaw but without the maxillary sinus present in the field of view, were excluded (n = 40). This led to a total of 139 CBCTs in 134 patients being selected for further evaluation. The mean age of the patients was 17.5 years, and the median was 13.9 years. Sixty-three (45.3%) patients were men and 76 (54.7%) were women.

Methods

All CBCT images were taken using a small FOV (4 × 4, 6 × 6 or 8 × 8 cm; 3 DX Accuitomo XYZ Tomograph; Morita Corp., Tokyo, Japan) and a voxel size of 0.125 mm. The data were reconstructed in slices and examined slice by slice in all three dimensions (sagittal, coronal, and axial) on 1:1 scaled images on the One Data Viewer Plus (Morita Corp., Tokyo, Japan) using an HP Compaq dc7900 Convertible Minitower (Hewlett-Packard Schweiz GmbH, Dübendorf, Switzerland) and

a 21-inch NEC MultiSync LCD 2190UXp monitor with a resolution of 1600 × 1200 pixels (NEC Corp., Tokyo, Japan). When needed, the magnifying tool and the ruler of the viewer were used.

All CBCT scans were reviewed by an orthodontist (PP) and by a board-certified medical radiologist (AP) independently. The reviewers looked for all incidental maxillary sinus findings and recorded them. The incidental findings were grouped by both observers into the following categories: 1) acute inflammatory and/or allergic disease, 2) chronic inflammatory and/or allergic disease, 3) malformation and bone dysplasia, 4) primary and secondary neoplastic disease, 5) metabolic disease, and 6) other [modified according to Burgener & Kormano (15) and Felson & Reeder (16)]. The two reviewers agreed in 133 of the 139 included cases, resulting in an interrater classification agreement of 95.7% (95% CI: 90.9–97.9%). The six cases with differences in the diagnosis were discussed, and disagreement was resolved by consensus.

The patient's age and gender and the size of the field of view were also recorded. Furthermore, based on the date it was performed, each CBCT was assigned to the corresponding season (summer, autumn, winter, or spring) to identify any seasonal dependence of the pathological findings. In addition, the thickness of the Schneiderian membrane was measured using the measuring tool of the One Data Viewer Plus at three representative positions (a, b, c) in the coronal scan. Position b was chosen to be the deepest point of the recess of the maxillary sinus in the coronal views, and positions a and c were symmetrically 5 mm to the buccal and palatal directions (Fig. 1). The precision of this measurement was double the voxel size of the CBCT used – that is, 0.25 mm.

Statistics

First, the mean for all measurements in the coronal CBCT images (a, b, and c) and the corresponding 95% confidence intervals were calculated. In addition, the mean CBCT measurements and the corresponding 95% confidence intervals were calculated for male and female patients separately, as well as for the season the CBCT image was taken. Fisher's exact test was used to evaluate a potential influence of gender, size of the field of view (4 × 4, 6 × 6 or 8 × 8 cm), and the season on the incidence of pathological findings in the maxillary sinus. The two-sample Wilcoxon rank-sum test was used to analyze the influence of the patient's age on the incidence of pathological findings diagnosed in the CBCT images.

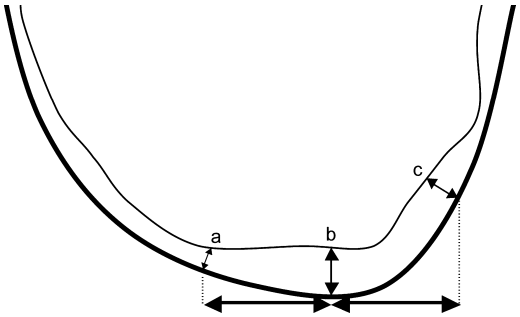

Fig. 1. Measurement of the thickness of the Schneiderian membrane at three different locations (a, b, c) on a schematic coronal view of the maxillary sinus. (b) Deepest point of the recess of the maxillary sinus; (a/c) 5 mm to the facial or palatal side.

The significance level chosen for all statistical tests was $p \leq 0.05$. All analyses were performed using the software package STATA 11 (StataCorp., College Station, TX, USA).

Results

In 65 (46.8%) of 139 CBCTs, incidental maxillary sinus findings were discovered that were not linked to the primary orthodontic indication for radiographic image taking. They belonged to the following categories: 1) acute inflammatory and/or allergic disease (five findings; 3.6%) and 2) chronic inflammatory and/or allergic disease (60 findings; 43.1%). No signs of inflammatory bone diseases or bone malignancies were diagnosed in the present patient population.

As all incidental findings were suspected mucosal pathologies, they were further differentiated into three descriptive types: flat mucosal thickening (> 1 mm) (33 CBCTs/23.7%/Fig. 2A–C), polypoid mucosal thickening (27 CBCTs/19.4%/Fig. 3A–C) and signs of acute sinusitis (five CBCTs/3.6%/Figs 4A–C and 5A–C).

Analysis of a potential influence of gender on the incidental findings in the maxillary sinuses revealed no statistically significant difference ($p = 0.294$). However, age was found to play a statistically significant role in the incidence of pathological findings in the maxillary sinus ($p = 0.022$). Patients with a suspected pathology had a mean age of 16.2 years (95% CI: 13.7–18.6), whereas patients with no incidental findings in their

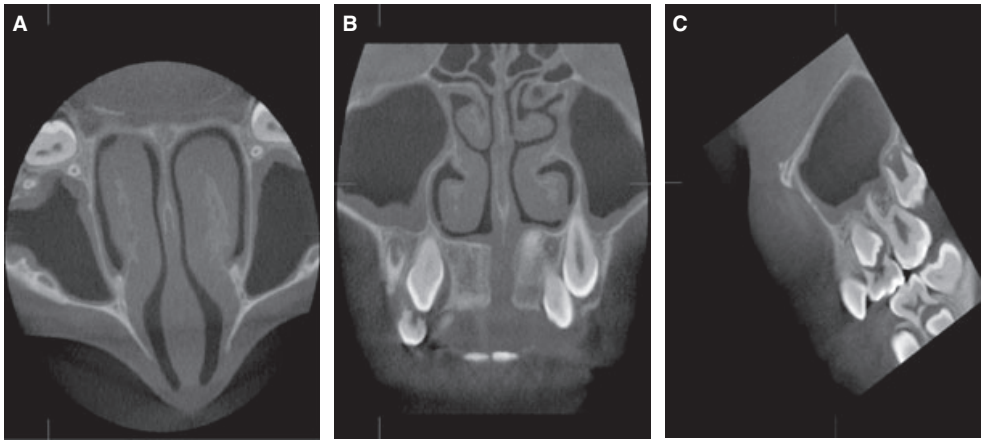

Fig. 2. Representative cone-beam computed tomography scans of a flat mucosal thickening in an 11-year-old male patient: (A) axial scan; (B) coronal scan; and (C) sagittal scan.

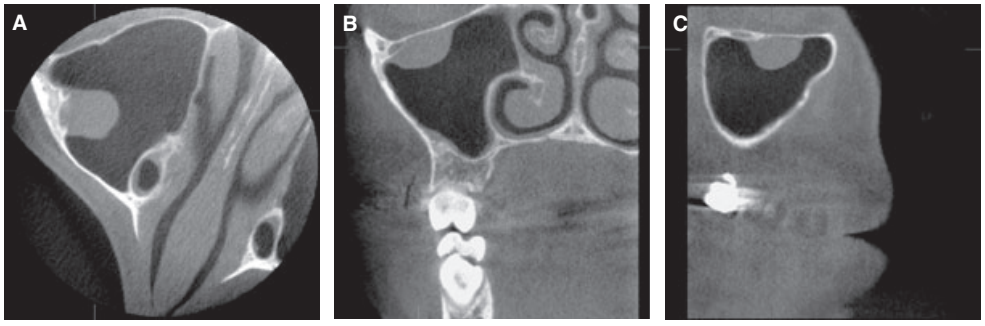

Fig. 3. Representative cone-beam computed tomography scans of a polypoid mucosal thickening in a 10-year-old male patient: (A) axial scan; (B) coronal scan; and (C) sagittal scan.

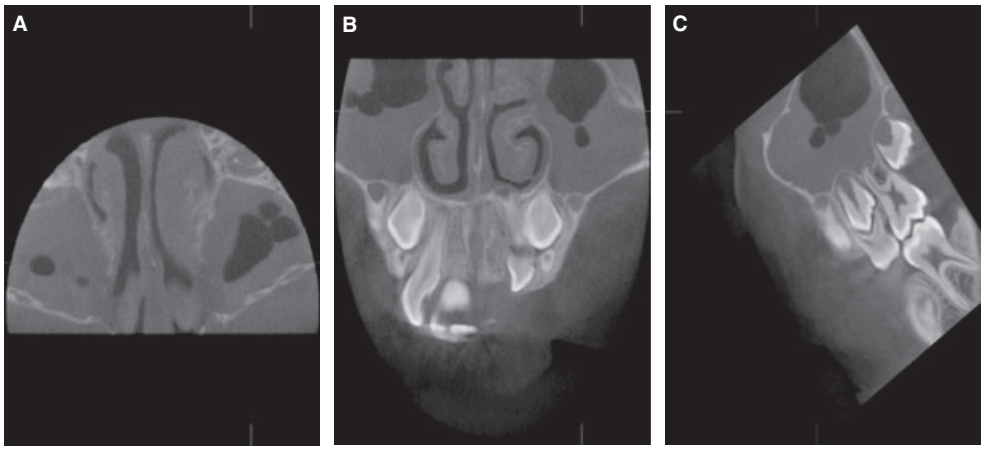

Fig. 4. Representative cone-beam computed tomography scans of signs of acute sinusitis in an $8^{1}/_{2}$-year-old female patient: (A) axial scan; (B) coronal scan; and (C) sagittal scan.

maxillary sinuses were an average of 19.9 years old (95% CI: 16.4–21.4).

With regard to the season (summer/autumn/winter/spring) when the CBCT was taken, the highest incidence rate for incidental pathological findings in the maxillary sinus was observed in the winter (19 findings out of 33 CBCTs taken; 57.6%; Table 1). Fisher's exact test did not show a statistically significant difference between the percentages of incidental findings for the different seasons ($p = 0.367$). Most of the incidental pathological findings were diagnosed on CBCTs with a field of view measuring 6 × 6 cm (37 out

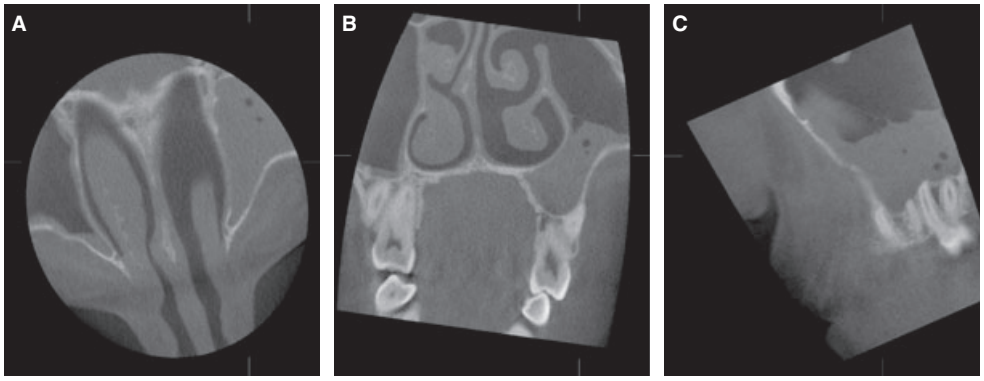

Fig. 5. Representative cone-beam computed tomography scans of mixed findings in a 13-year-old male patient: (A) axial scan; (B) coronal scan; and (C) sagittal scan. The right sinus presents a flat mucosal thickening and the left sinus shows signs of acute sinusitis.

Table 1. **Types of findings and thickness of Schneiderian membrane sorted by season, as diagnosed on cone-beam computed tomography (CBCT) images with a limited FOV (N = 139)**

Season	Number of CBCTs	Pathology in maxillary sinus [yes/no], %	Type of finding (0–3)			Mean thickness a in mm (95% CI)	Mean thickness b in mm (95% CI)	Mean thickness c in mm (95% CI)	Mean overall thickness in mm (95% CI)
Spring	48	18 (37.5)	0	30	62.5%	1.10 (0.62–1.58)	1.4 (0.75–2.05)	1.15 (0.77–1.53)	1.21 (0.72–1.70)
			1	11	22.9%				
			2	6	12.5%				
			3	1	2.1%				
Summer	32	16 (50.0)	0	16	50.0%	1.70 (0.70–2.69)	2.58 (1.00–4.16)	2.22 (0.98–3.45)	2.16 (0.96–3.36)
			1	8	25.0%				
			2	5	15.6%				
			3	3	9.4%				
Autumn	26	12 (46.1)	0	14	53.8%	1.07 (0.52–1.60)	1.52 (0.76–2.27)	0.90 (0.48–1.32)	1.16 (0.61–1.72)
			1	6	23.1%				
			2	5	19.2%				
			3	1	3.8%				
Winter	33	19 (57.6)	0	14	42.4%	1.76 (0.90–2.61)	2.01 (0.85 – 3.17)	1.82 (0.83–2.81)	1.86 (0.88–2.84)
			1	8	24.2%				
			2	11	33.3%				
			3	0	0.0%				
Total	139	65 (46.8)	0	74	53.2%	1.39 (1.03–1.73)	1.84 (1.32–2.35)	1.51 (1.11–1.90)	1.58 (1.17–1.98)
			1	33	23.7%				
			2	27	19.4%				
			3	5	3.6%				

of 65; 56.9%), but there was no statistically significant difference between the different fields of view ($p = 0.473$).

The mean thickness for the Schneiderian membrane at the deepest point of the recess of the maxillary sinus in the coronal CBCT view (b) was 1.84 mm (Table 1). The corresponding measurements on the buccal and palatal sides were 1.39 mm (a) and 1.51 mm (c), respectively. The range of measurements varied from 0.1 to 19.3 mm. The overall mean thickness of the mucosal lining in the maxillary sinus was 1.58 mm, with a 95% CI of 1.17–1.98 mm.

Discussion

The goal of this study was to determine the frequency of incidental findings in the maxillary sinus and the dimensions of the Schneiderian membrane in CBCTs with a limited FOV made for orthodontic purposes. Out of 139 CBCTs, 65 (46.8%) showed collateral pathologies or incidental findings. Because the entire sinus was not visible for all included patients using a limited CBCT imaging technique, the frequency of incidental findings might have been even greater if a larger FOV had been used. Three types of radiological findings were found in the patients included: flat mucosal thickening, polypoid mucosal thickening, and signs of acute sinusitis.

A recent systematic review of the medical radiology literature (17) found that incidental findings occurred with a mean frequency of 23.6% in 44 reviewed papers. The frequency of incidental findings was even higher in studies involving CT technology (31.1%). With CBCT imaging, a radiographic technique similar to CT imaging is available for dental purposes. In orthodontics, surface-rendered 3D reconstructions are often evaluated, rather than the sagittal, coronal, or axial scans separately. This increases the likelihood that collateral pathologies and incidental findings will be overlooked. Even in the typically young orthodontic patients, rare but devastating pathological processes can be found and may be diagnosed initially using CBCT imaging, as recent case reports confirm (13, 14, 18). Interestingly, the size of the FOV used for this study did not have a statistically significant effect on the frequency of incidental findings. However, this finding should be considered with some caution, as every attempt was made to apply the smallest possible FOV to comply with the ALARA principle. Therefore, in this study only two CBCTs were performed using an 8×8 cm FOV.

Many studies using CT and MRI imaging performed in the ear–nose–throat field confirm a high prevalence of incidental findings without initial clinical symptoms. Havas et al. (19) reported radiological abnormalities in one or more of the paranasal sinuses in up to 42.5% of MRI and CT scans of asymptomatic patients with an average age of 55 years. Lim et al. (20) registered 32.3% sinus abnormalities in non-ENT MRI images of children below the age of 16 years. In contrast, symptomatic sinus patients are much more likely to have positive sinus CT scan findings than asymptomatic patients (21). In this study, we did not consider the clinical history of the scanned patients. It has been reported in the literature that the correlation between radiological airway findings and clinical symptoms is generally weak (22).

A recent study evaluated incidental findings in 500 CBCT scans with large FOVs made for orthodontic, TMJ, endodontic, and implant indications (12). In this study, an overall incidental finding rate of 24.6% was reported. In the orthodontic group, incidental findings were confirmed in 21.4%, and findings related to the upper airways, such as retention cysts, polyps, and (rhino)-sinusitis, were reported in only 14.3% of patients. In our patient group, the prevalence of incidental findings was much higher (46.8%), although the study population was comparable. Other reports (19, 20) confirm our range of incidental findings. Interestingly, Cha et al. (12) found 61% of airway findings in patients younger than 16 years. In our study, the same trend seems to be confirmed, as patients with incidental findings had a mean age of 16.2 years (95% CI: 13.7–18.6), whereas patients with no incidental findings in their maxillary sinuses had a mean age of 19.9 years (95% CI: 16.4–21.4). Other studies also demonstrated that cysts and polyps in the sinuses occurred most often in patients under the age of 16 and that sinusitis occurred most often in 20- to 30-year-olds (23, 24).

Existing data on the dimensions and changes in the Schneiderian membrane based on radiographic imaging are rare in the literature. In CT and MRI studies, the coronal view is well established for evaluating the mucosal thickness in the maxillary sinus, and the measurements are always performed perpendicularly to the underlying bone (25–29). Historically, 2 mm was considered a reliable threshold for pathological mucosal swelling (29). The results of this study confirmed the great interindividual variability of the thickness of the Schneiderian membrane, with values ranging from 0.10 (minimum) to 19.30 mm (maximum). The Schneiderian membrane was the thinnest in the buccal measurements, with slightly higher values in the palatal aspect, and the highest values in the mid-sagittal aspect. It can be speculated that the mid-sagittal thickness values are increased because of the seated patient position during CBCT image taking, which could cause the accumulation of mucous secretions in the deepest aspect of the maxillary sinus. Other imaging techniques, such as MRI, CT and sometimes CBCT,

perform image taking on a prone patient. Moreover, CBCT imaging does not allow differentiation between liquids and soft tissue. Therefore, the high mean/-median values for the mid-sagittal measurements could also be partially attributed to mucous accumulation on the Schneiderian membrane.

In our study, no signs of osteomyelitis or bone malignancy were found. This does not mean, however, that pathologies with a low incidence rate are never present in a young orthodontic patient group. Bornstein et al. (18) recently presented a case of Ewing's sarcoma in a 19-year-old female whose CBCT imaging revealed proliferation of soft tissue in the maxillary sinus, osteolytic destruction of maxillary bone, and resorptive signs in roots of molars. This underlines the necessity of systematically screening CBCT slices in all three dimensions (axial, coronal, and sagittal) with adequate care. Because of the high incidence of collateral pathologies and incidental findings, all CBCT scans should ideally be interpreted together with other specialists if unusual findings are present, to avoid under- or overestimation of a potential pathology. Furthermore, a concise diagnostic report should be provided for all CBCTs performed, as requested by the American Academy of Oral and Maxillofacial Radiology, which stated: 'Just as a pathology report accompanies a biopsy, an imaging report must accompany a CBCT scan' (30).

Conclusions

From the findings of this study, the following conclusions can be drawn:

1 Incidental findings were present in almost half of the CBCTs with a limited FOV performed in a younger orthodontic patient population. There were three types of findings: 1) flat mucosal thickening (33 CBCTs/23.7%), 2) polypoid mucosal thickening (27 CBCTs/19.4%), and 3) radiological signs of acute sinusitis (five CBCTs/3.6%).
2 The frequency of incidental findings seemed not to be directly related to gender, season of imaging, or FOV.
3 The only statistically significant factor influencing the frequency of incidental findings in CBCT scans was the age of the patient, although further research is needed to clarify the clinical significance of this result.

Clinical relevance

This study shows that even in CBCT images with a limited field of view ($4 \times 4/6 \times 6/8 \times 8$ cm) incidental findings of the maxillary sinus are present at a high rate (46.8%). Therefore, when using three-dimensional imaging, not only surface-rendered 3D reconstructions should be looked at, but all CBCT slices should be systematically screened in all three dimensions (axial, coronal, and sagittal). When there are incidental findings, they should be interpreted together with other specialists to avoid under- or overestimation of potential pathology. The authors encourage the development of guidelines for the use and the interpretation of three-dimensional images made for orthodontic purposes.

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