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ORIGINAL ARTICLE

Frequency and type of incidentally detected radiodensities in the maxillary sinus: a retrospective analysis using cone beam computed tomography (CBCT)

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Abstract

Objectives To evaluate the frequency, location, and characteristics of radiodensities in the maxillary sinus using cone beam computed tomography (CBCT).

Materials and methods All CBCT scans with a large field of view with both maxillary sinuses entirely visible were initially screened. Patients were included, if there was no suspicion of sinus pathology and no history of surgical intervention/trauma in the sinus region. The location and shape of the radiodensities were evaluated in axial, coronal, and sagittal CBCT views. The findings were correlated with age, gender, condition of the sinus mucosa, and status of the dentition.

Results A total of 169 patients (338 maxillary sinuses) were included. Radiodensities were found in 35 sinuses (10.4%) of 28 patients (16.6%) with a mean age of 32.0 years. Most of the 35 affected sinuses had one radiodensity (19/54.2%). The radiodensities were typically located at the sinus floor (22/62.9%). Of the sinuses presenting with radiodensities, 17 (48.6%) were exhibiting reactive changes of the Schneiderian membrane. The presence of periodontal pathology was found to be associated with the presence of radiodensities. Age and sinus pathology were influencing factors on the shape of radiodensities, and the status of the dentition was an influencing factor on the number of lesions.

Conclusions One-sixth of the patients analyzed had incidentally diagnosed radiodensities in their maxillary sinuses. As almost 50% of the sinuses with radiodensities exhibited a form of chronic rhinosinusitis, the diagnosed ectopic calcifications may have formed as a result of mucosal changes of inflammatory origin. The presence of periodontal pathology was associated with a higher incidence of radiodensities. Nevertheless, this finding has to be interpreted with some caution due to the limited sample size available.

Clinical relevance Incidentally detected radiodensities in the maxillary sinus are not an infrequent finding in CBCT scans of asymptomatic patients, and are located typically on the sinus floor. Future studies are needed to assess the clinical significance of these findings especially with regard to planned surgical interventions in the posterior maxilla.

Keywords Maxillary sinus · Radiodensity · Cone beam computed tomography · Frequency · Location

Introduction

Cone beam computed tomography (CBCT) has become a widely used modality for diagnostic imaging in the oral and maxillofacial region [1]. Currently, there are many different CBCT devices on the market, which have various features such as fields of view (FOV), voxel sizes, and radiation doses [2, 3]. When dental practitioners use CBCT in their daily practice, they should evaluate not only the region of interest, but also neighboring regions depicted in the volume to account for potential incidental findings. This recommendation to assess the entire data set of a CBCT scan has also been

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given by the European Academy of Dental and Maxillofacial Radiology [4].

Several articles reporting on incidental findings in CBCT scans have been published [5–10]. Such incidental findings in CBCT scans were found in the dentoalveolar regions [5, 6, 8], the maxillary sinus [9, 10], and naso-oropharyngeal airway spaces [7]. However, it has been noted that the frequency of these findings also depends on various factors such as the population studied, the FOV applied, and the location/disease focused on (e.g., the region of interest) [5–10].

Several professional organizations have advocated the use of CBCT as a diagnostic imaging modality to assess the bone condition in the posterior maxilla and the health of the maxillary sinus before the insertion of dental implants [11–13]. Following a loss of posterior teeth in the maxilla, alveolar bone tends to resorb gradually, which leads to a decreased bone height and width. The alveolar bone resorption and the shape of the maxillary sinus may pose anatomical limitations for implant insertions [14]. To deal with this problem, sinus floor elevation (SFE) procedure using a transcrestal or lateral window approach has become a well-accepted surgical option to regain the missing vertical bone dimension [15]. To perform SFE procedures, it is critical to confirm a healthy condition of the maxillary sinus, and to exclude any pathology that might contraindicate dental implant placement preoperatively [16].

Radiodensities in the maxillary sinus are considered as relatively rare findings [6, 7, 9]. It is primarily known as a characteristic radiographic sign for aspergillosis in the paranasal sinuses [17]. Characteristic symptoms of aspergillosis are nasal obstruction, nasal discharge, and the typical inflammatory changes of the sinus mucosa such as highly radiopaque radiopacities that can be clearly seen in the respective CT images [17–19]. Although the existence of radiodensities in the maxillary sinus has been reported in previous CBCT/CT studies as a secondary outcome, there has been no study primarily focusing on morphology and characteristics of incidental radiodensities within the entire sinuses [9, 10]. Therefore, the prevalence, typical location, and dimensions of such radiodensities and their potential relationship with the status of the neighboring teeth remain unknown to date.

The objective of the present study was to evaluate the frequency, location, and different types of radiodensities in the maxillary sinus using CBCT images. Additionally, potential influencing factors such as gender, age, alterations of the sinus mucosa, and dental pathology in the posterior maxilla were assessed.

Material and methods

Study sample

This study screened all CBCT scans with a large FOV that were performed between February 2016 and August 2017 at Oral and Maxillofacial Radiology, Faculty of Dentistry, The University of Hong Kong. The indications for these CBCT scans varied from dental implant planning, orthognathic surgery planning, removal of impacted teeth, to an evaluation of cysts and neoplasias. Each scan was acquired with a ProMax 3D Mid (Planmeca, Helsinki, Finland) CBCT machine. The CBCT data sets were included, if both maxillary sinuses were entirely visible in the scan and there was no history of surgical intervention/trauma in the sinus region.

The CBCT images were excluded from this study if

(1) both maxillary sinuses were not entirely visible;
(2) imaging was performed due to suspected sinus pathology including confirmation of a sinus radiodensity;
(3) there was a history of surgical intervention/trauma to the maxillary sinus;
(4) pathology from anterior teeth (canine-to-canine) impinged into the maxillary sinuses;
(5) examinations exhibited insufficient image quality in the sinus region due to artifact from acquisition or patient movement.

The medical history of the included patients was searched for demographic data including gender and age at the time of imaging. The study was conducted in full accordance with the Declaration of Helsinki 2013 (www.wma.net). The study protocol was submitted to and approved by the local institutional review board (IRB) of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (approval number UW 17-462).

CBCT image analysis

CBCT images were all analyzed on a Philips 223V LED monitor with a resolution of 1920 × 1080 pixels (Philips, Amsterdam, Netherlands). Data were reconstructed with slices of 0.5 mm thickness and a 0.4 mm voxel size. The image observations were performed using the software of the CBCT device (ROMEXIS Version 4.4.0.R, Planmeca, Helsinki, Finland). Two oral and maxillofacial radiologists (R. T. and T. K.) performed all observations twice with a time gap of a minimum of 2 weeks between each observation to test for intra-observer (repeatability) and inter-observer agreement (reproducibility).

Before further data analysis, the observers discussed the inconsistent findings and diagnoses to reach a consensus. The agreed findings about frequency, location, and shape of the radiodensities were then utilized for further reporting and analysis.

For the detailed assessment of the incidentally diagnosed radiodensities in the maxillary sinuses, the observers evaluated the following:

- The location of the radiodensities in the maxillary sinus according to Schriber et al. [20]:

  (1) Floor, at the region adjacent to the bottom part the sinus corresponding to the maxillary alveolar process
  (2) Walls (including anterior, posterior, lateral, and medial walls)
  (3) Roof, at the region adjacent to the floor of the orbit
  (4) Multiple sites (combinations of locations mentioned above)
- The number of the radiodensities: (1) single and (2) multiple.
- Shape of the radiodensity: (1) round/oval, (2) linear/flat (along with the sinus wall), (3) irregular (e.g., star shaped), (4) mixed.
- Contact with sinus wall: (1) direct contact and (2) no contact.

To assess the potential relationship between the incidentally detected radiodensities and the status of the sinus mucosa, the morphological changes of the Schneiderian membrane and its bony lining were recorded and coded based on criteria adapted and modified from Soikkonen and Ainamo (1995), which was also used in several previous studies [16, 21–23]:

(0) Inconspicuous/no thickening of the sinus membrane;
(1) Flat, shallow thickening of the Schneiderian membrane (> 2 mm);
(2) Flat, shallow thickening of the Schneiderian membrane (> 4 mm);
(3) Semispheric thickening of the membrane (suspected mucous retention cyst);
(4) Complete opacification of the sinus;
(5) Mixed flat and semispherical thickenings; or
(6) Other (e.g., bone destruction, cyst, foreign body, suspected neoplasia).

For all cases, the status of the dentition (from first premolar to second molar) with regard to the maxillary sinus under investigation was classified into completely edentulous, partially edentulous, and dentate. If teeth were present, their status was evaluated to account for potential endodontic or periodontal pathology that could influence the status of the maxillary sinus. The endodontic status of the teeth in the respective posterior maxilla was classified into (assigning the largest code value whenever applicable) the following:

(1) No endodontic pathology or treatment;
(2) Endodontic treatment(s) without visible apical hypodensity;
(3) Apical hypodensity with or without visible endodontic treatment(s).

Similarly, teeth with periodontal pathology were classified according to the methodology described by Janner et al. [24] and Yeung et al. [23] into (assigning the largest code value whenever applicable) the following:

(1) No periodontal lesions;
(2) Horizontal and/or vertical periodontal bone loss deeper than the midlevel of the respective root without furcation involvement;
(3) Horizontal and/or vertical periodontal bone loss with furcation involvement.

Statistical analysis

All data were analyzed descriptively. For intra-observer repeatability and inter-observer reproducibility, Cohen kappa values were calculated [25]. The evaluations of influencing factors on the presence of radiodensities were done on the patient level (age and gender) and the sinus level (sinus pathology, status of dentition, endodontic, and periodontal pathology) respectively. Furthermore, the evaluations of influencing factors on the characteristics of radiodensities were done on the sinus level (age, gender, sinus pathology, dental status on posterior maxilla, endodontic, and periodontal pathology) for sinuses with confirmed lesions.

To account for the possible patient clustering effect, the significance of the possible influencing factors on the presence and characteristics of the radiodensities were evaluated with logistic regression using a univariate generalized estimating equations (GEE) model. The significance level chosen for all statistical tests was $p < 0.05$. All analyses were performed in SPSS (Version 24.0, IBM Corp., Armonk, NY, USA).

Results

Patient population

Initially, a total of 222 CBCT scans with a large FOV were screened. From these, 53 CBCT scans were excluded according to the exclusion criteria. Thus, a total of 169 CBCT scans (338 sinuses) fulfilled the inclusion criteria. The 169 patients consisted of 108 females and 61 males with a mean age of 28.7 years (range from 7 to 82 years). The FOV (in millimeter, diameter × height) of CBCT scans was 20 × 17 for 140 patients and 20 × 10 for 29 patients. The most frequent indication for the scans was planning of maxillofacial surgeries (69 out of 169 scans/40.8%).

Intra- and inter-observer agreement

Intra-observer repeatability was very high for both observers regarding the presence (Kappa values/$\kappa = 0.982$ and $\kappa = 0.927$, respectively) and location ($\kappa = 0.873$ and $\kappa = 0.925$, respectively) of the radiodensities. The repeatability regarding the contact with the wall exhibited moderate to substantial values ($\kappa = 0.459$ and $\kappa = 0.731$, respectively). The repeatability regarding the number ($\kappa = 1.00$ and $\kappa = 0.752$, respectively) and shape ($\kappa = 0.628$ and $\kappa = 0.748$, respectively) of the radiodensities was substantial to very high. Inter-observer reproducibility for the variables mentioned ranged from a moderate to a substantial agreement ($\kappa = 0.417$–0.751).

Frequency and characteristics of the radiodensities in the maxillary sinuses

There were 35 sinuses (16 left, 19 right/10.4% of the sinuses analyzed) in 28 patients (8 male, 20 female/16.6% of all patients) with radiodensities (Table 1). Each of the eight males had one sinus with radiodensities (4 left, 4 right). The 20 females had 27 sinuses (12 left, 15 right) with radiodensities, with seven of them having lesions on both sides. The mean age of the 28 patients included with radiodensities in the 35 sinuses was 32.0 years (Table 1).

Radiodensities were observed most frequently on the maxillary sinus floor (22 sinuses/62.9%). In 19 of the 35 sinuses with radiodensities (54.3%), there was only one lesion. Five sinuses (14.3%) had four of more radiodensities (Table 2, Fig. 1). The radiodensities had various shapes, with the linear/flat type being the most common (12 sinuses/34.3%; Fig. 2). Radiodensities in 23 sinuses (65.7%) had a direct contact with the sinus wall (Table 2).

Most of these 35 sinuses with an incidentally diagnosed radiodensity were associated with a fully dentate dentition (22/62.9%), with no mucosal changes (18/51.4%), no endodontic pathology (33/94.2%), and with no periodontal disease in the posterior maxilla (32/91.4%; Table 3). Nevertheless, a total of 17 (48.6%) maxillary sinuses detected with radiodensities exhibited morphological changes of the mucosa, which in most instances (15 out of 17) were flat, shallow thickenings of the Schneiderian membrane measuring more than 2 or even 4 mm on the respective CBCT images (Table 3).

Table 1 Descriptive data of patients and sinuses with and without radiodensities

	With radiodensity	Without radiodensity	Total
Patient level			
Mean age (SD)	32.0 (15.4)	28.3 (12.5)	28.7(12.9)
Male	8 (13.1%)	53 (86.9%)	61 (100%)
Female	20 (18.5%)	88 (81.5%)	108 (100%)
Total	28 (16.6%)	141 (83.4%)	169 (100%)
Sinus level			
Left	16 (9.5%)	153 (90.5%)	169 (100%)
Right	19 (11.2%)	150 (88.8%)	169 (100%)
Total	35 (10.4%)	303 (89.6%)	338 (100%)

Potential influencing factors on the characteristics of the radiodensities in the maxillary sinuses

The analysis showed that gender, age, sinus pathology, status of dentition, and endodontic status did not have a significant influence on the presence of radiodensities (Table 4). Meanwhile, the presence of periodontal pathology was associated with a higher incidence of radiodensities in the maxillary sinus resulting in a borderline significance (odds ratio/OR = 5.59, $p = 0.046$; Table 4).

Regarding the characteristics of the radiodensities, age and sinus pathology were significant influencing factors (Table 5). Increasing age was associated with a lower chance of having a round/oval shape of the radiodensities (OR = 0.77, $p = 0.033$), but a higher chance of having an irregular shape (OR = 1.08, $p = 0.002$). Presence of mucosal changes in the sinus was positively associated with the presence of radiodensities with a linear/flat configuration (OR = 11.43, $p = 0.010$).

Regarding the number of radiodensities, the dentition in the posterior maxilla was a significant influencing factor (Table 5). Partial/complete edentulism was positively associated with the presence of multiple radiodensities (OR = 8.57, $p = 0.010$).

Discussion

The presence of radiodensities in the maxillary sinus was found in 28 out of the 169 patients (16.6%) included, or 35 of the 338 sinuses (10.4%). The frequency of radiodensities in the maxillary sinus in the present study is considerably higher than that reported in previous papers (0.7 to 2.4%), which assessed radiodensities in the sinus among other incidental findings as a secondary outcome during evaluation of CBCT scans [6, 26–28]. In the current study, there were seven patients in which radiodensities were found bilaterally, all of whom were females. This female predominance could be due to the higher ratio of female patients in the population of the present study.

In this study, the presence of a sinus radiodensity was made by two maxillofacial radiologists with a high intra-observer repeatability ($\kappa = 0.982$ and $\kappa = 0.927$, for each observer respectively) and inter-observer reproducibility ($\kappa = 0.751$). However, the reproducibility of the shape of the radiodensities

Table 2 Characteristics regarding morphology and location of the radiodensities diagnosed in 35 maxillary sinuses (out of 338)

	Overall number (percentage)	Male/female number (percentage)	Mean age (years) male/female
Location			
(1) Floor	22 (62.9)	4 (50.0)/18 (66.7)	24.0/36.2
(2) Walls	5 (14.3)	3 (37.5)/2 (7.4)	27.0/32.5
(3) Roof	0	0 (0)/0 (0)	–
(4) Multiple	8 (22.8)	1 (12.5)/7 (25.9)	36/30.9
Number			
(1) One	19 (54.2)	5 (62.5)/14 (51.9)	24.8/29.8
(2) Two	7 (20.0)	2 (25.0)/5 (18.5)	30.5/29.8
(3) Three	4 (11.4)	1 (12.5)/3 (11.1)	28/22.7
(4) Four or more	5 (14.3)	0 (0)/5 (18.5)	–/54.4
Shape			
(1) Round/oval	5 (14.3)	0 (0)/5 (18.5)	–/22.6
(2) Linear/flat	12 (34.3)	5 (62.5)/7 (25.9)	27.0/29.0
(3) Irregular	8 (22.9)	2 (25.0)/6 (22.2)	26.5/53.8
(4) Mixed	10 (28.6)	1 (12.5)/9 (33.3)	25/29.7
Contact with sinus wall			
(1) Direct contact	23 (65.7)	5 (62.5)/18 (66.7)	24.8/31.4
(2) No contact	12 (34.3)	3 (37.5)/9 (33.3)	29.7/37.9

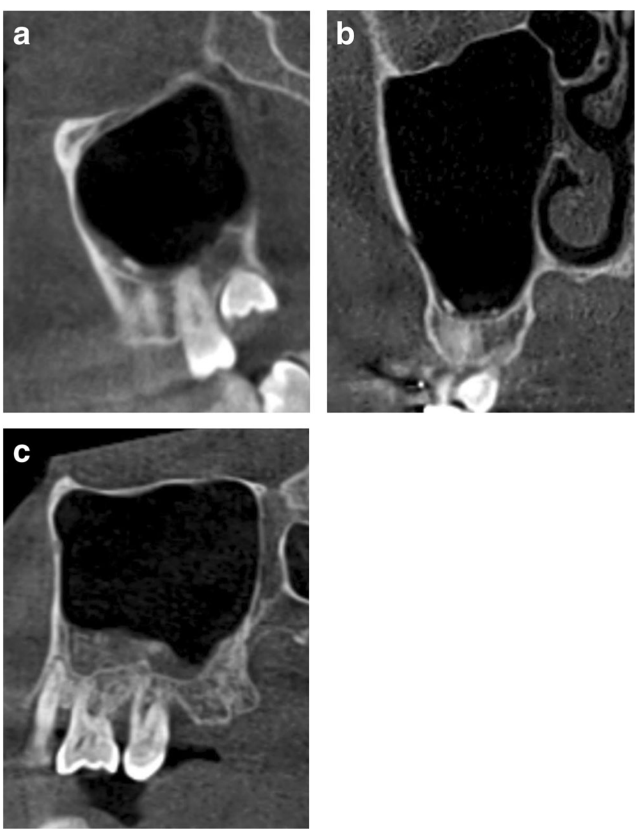

Fig. 1 Representative CBCT images of radiodensities in the maxillary sinus. **a** Maxillary sinus with one lesion on the floor. **b** Maxillary sinus with two lesions on the floor. **c** Multiple radiodensities in the thickened Schneiderian membrane on the floor of the maxillary sinus

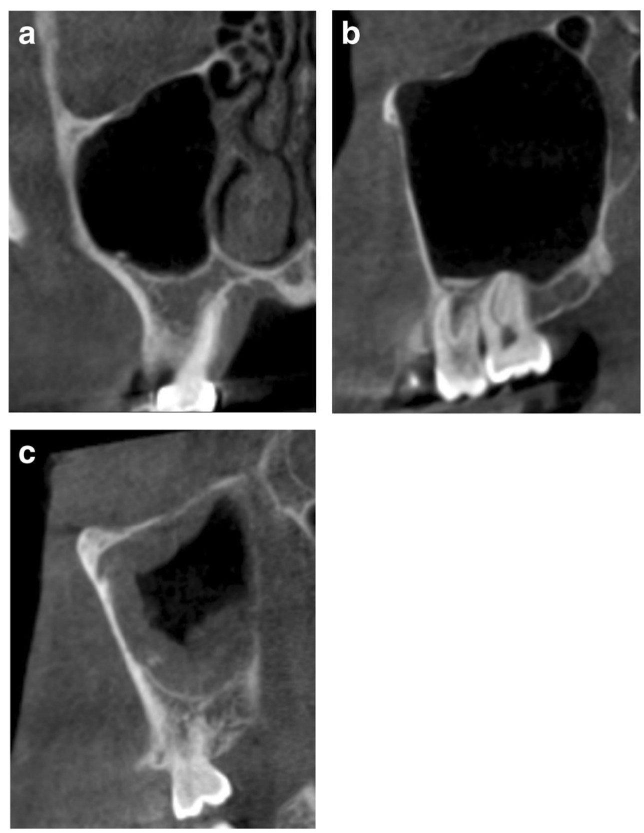

Fig. 2 Representative CBCT images of characteristic shapes of radiodensities in the maxillary sinus. **a** Maxillary sinus with a round/oval-shaped radiodensity on the floor. **b** Maxillary sinus with a linear/flat-shaped radiodensity on the floor. **c** Maxillary sinus with an irregular-shaped radiodensity on the floor

Table 3 Status of the dentition, status of the maxillary sinus, and dental pathology (periodontal and endodontic) associated with the observed radiodensity

	With radiodensity	Without radiodensity
Status of dentition (first premolar to second molar)		
(1) Dentate	22 (62.9%/9.5%)*	209 (69.0%/90.5%)*
(2) Partially edentulous	12 (34.2%/12.4%)	85 (28.1%/87.6%)
(3) Completely edentulous	1 (2.9%/10.0%)	9 (3.0%/90.0%)
Sinus pathology		
(0) No thickening	18 (51.4%/8.7%)	190 (62.7%/91.3%)
(1) Flat shallow thickening > 2 mm	10 (28.6%/22.7%)	34 (11.2%/77.3%)
(2) Flat shallow thickening > 4 mm	5 (14.3%/17.9%)	23 (7.6%/82.1%)
(3) Semispheric thickening	2 (5.7%/4.4%)	43 (14.2%/95.6%)
(4) Complete opacification	0	4 (1.3%/100.0%)
(5) Mixed (flat and semispherical)	0	9 (3.0%/100.0%)
(6) Other	0	0
Endodontic status		
(1) No endodontic pathology or treatment	33 (94.2%/12.1%)	282 (93.1%/87.9%)
(2) Endodontic treatment without visible apical hypodensity	1 (2.9%/8.3%)	11 (3.6%/91.7%)
(3) Apical hypodensity with or without visible endodontic treatment	1 (2.9%/9.1%)	10 (3.3%/90.9%)
Periodontal pathology		
(1) No periodontal lesions	32 (91.4%/9.7%)	298 (98.3%/90.3%)
(2) Horizontal/vertical periodontal bone loss without furcation	0	0
(3) Horizontal/vertical periodontal bone loss with furcation	3 (8.6%/37.5%)	5 (1.7%/62.5%)

*Percentages are indicated first for columns, then for rows

and their contact with the sinus wall was only moderate (κ = 0.486 and κ = 0.417). The reason for these variable values is that many radiodensities were relatively small, and therefore, it was difficult for the observers to judge if there was a direct contact with the sinus wall or not. In addition, the relatively large voxel size (0.4 mm) of the image used due to the large FOV of the scans included in the present study might also have affected the outcome.

Radiopacities found in the maxillary sinus are originating from various sources such as root fragments, an osteoma, an odontoma, periapical sclerotic osteitis, foreign bodies, sinus septa, or neoplasias including malignant diseases. Such radiopaque masses can be calcifications (which exhibit small rings or arcs), ossifications (with a trabecular pattern), or residual bone (for example, after destruction of adjacent bone) [29]. However, these findings can only be distinguished arbitrarily from each other based on CBCT/CT images as they are often very small, and it is difficult to assess the underlying physiological processes [29].

Yoon et al. [30] evaluated inflammatory calcifications in the maxillary sinus using computed tomography (CT) in 510 patients with a chronic maxillary sinusitis (fungal and nonfungal) and confirmed such calcifications in 36 patients. Out of these, 20 patients had a sinusitis of fungal origin and 16 patients a nonfungal sinusitis. Furthermore, they reported that most of the calcifications in fungal sinusitis were centrally located within the maxillary sinus, whereas the calcifications in patients with a nonfungal sinusitis were usually found at the periphery near the sinus wall. In present study, most of the radiodensities were observed at the periphery (near the sinus floor) and none at the center of the maxillary sinus. Thus, the possibility of the patients having radiodensities due to fungal maxillary sinusitis in the present population analyzed is considered small.

Although changes of the sinus mucosa did not seem to have a statistically significant influence on the presence of the radiodensities diagnosed in the present study, it is nevertheless a striking finding that almost 50% (17 out of 35) of these radiodensities were found in maxillary sinuses with various forms of mucosal alterations. As only asymptomatic patients

Table 4 Demographic and clinical factors as potential influencing parameters on the presence of sinus radiodensities

Influencing factors	*p* value
Gender	0.099
Age	0.217
Sinus pathology (the presence of thickening)	0.277
Dentition (full, partial edentulism, full edentulism)	0.770
Presence of endodontic pathology	0.781
Presence of periodontal pathology	*0.046*

Value in italics indicates statistically significant difference ($p < 0.05$)

Table 5 Demographic and clinical factors as potential influencing parameters on the type of sinus radiodensity (presence of radiodensity only)

	Influencing factor (odds ratio (95% confidence interval), p value)					
	Gender (female; reference group: male)	Age	Sinus pathology (thickening vs not thickening)	Dentition (partially/completely edentulous vs dentate)	Presence of endodontic pathology	Presence of periodontal pathology
1 Location						
Floor	2.00 (0.38–10.43) $p = 0.411$	1.01 (0.96–1.06) $p = 0.715$	*5.83 (1.23–27.56)* $p = 0.026$	0.54 (0.13–2.23) $p = 0.399$	NA	0.26 (0.01–4.64) $p = 0.361$
Walls	0.13 (0.02–1.04) $p = 0.054$	0.98 (0.94–1.03) $p = 0.462$	0.22 (0.02–2.31) $p = 0.206$	NA	NA	NA
Multiple	2.45 (0.24–24.98) $p = 0.449$	1.00 (0.94–1.06) $p = 0.933$	0.27 (0.04–1.64) $p = 0.154$	*8.57 (1.66–44.26)* $p = 0.010$	NA	8.67 (0.46–163.28) $p = 0.149$
2 Shape						
Round/oval	NA	*0.77 (0.61–0.98)* $p = 0.033$	NA	0.38 (0.04–3.83) $p = 0.408$	7.25 (0.37–141.33) $p = 0.191$	NA
Linear/flat	0.21 (0.04–1.18) $p = 0.077$	0.97 (0.93–1.02) $p = 0.249$	*11.43 (1.78–73.51)* $p = 0.010$	0.43 (0.09–2.20) $p = 0.312$	NA	NA
Irregular	0.86 (0.13–5.75) $p = 0.874$	*1.08 (1.03–1.13)* $p = 0.002$	2.08 (0.37–11.82) $p = 0.407$	1.02 (0.15–6.77) $p = 0.984$	3.71 (0.26–52.25) $p = 0.331$	1.79 (0.10–33.23) $p = 0.697$
Mixed	3.50 (0.35–35.28) $p = 0.288$	0.98 (0.92–1.05) $p = 0.582$	0.17 (0.02–1.63) $p = 0.124$	3.86 (0.78–19.15) $p = 0.099$	NA	6.00 (0.32–111.95) $p = 0.230$
3 Contact with the wall	0.83 (0.15–4.51) $p = 0.833$	1.02 (0.97–1.08) $p = 0.381$	1.82 (0.40–8.39) $p = 0.442$	1.34 (0.27–6.58) $p = 0.719$	2.00 (0.14–29.22) $p = 0.612$	0.95 (0.05–17.07) $p = 0.975$

Values in italics indicate statistically significant difference ($p < 0.05$)

NA, not applicable because there existed too few cases in those categories

were included in the present study, these patients were most likely exhibiting a form of chronic rhinosinusitis, which was then only incidentally detected by CBCT imaging. As this study was retrospective in nature, it cannot be determined clearly, whether these sinus mucosa reactions were from a rhinogenic or odontogenic origin. Nevertheless, evaluating potential influencing factors on the presence of radiodensities in the maxillary sinus, only periodontal pathology of teeth in the posterior maxilla was considered significant in the present study. However, since there were only eight cases with periodontal pathology and the p value only exhibited a borderline significance ($p = 0.046$), further investigation of a larger population seems to be necessary.

Analyzing potential influencing factors on the characteristics of the radiodensities, it was seen that increasing age was negatively associated with the presence of a round/oval shape, and positively associated with an irregular shape. Nevertheless, the difficulty in determining the exact shape of radiodensities should be taken in consideration, which is also highlighted by the only moderate inter-observer reproducibility. Furthermore, there was a relationship between changes in the sinus mucosa and the presence of radiodensities with a linear/flat shape. Since associations between periodontal pathology, mucosal changes, and characteristics of radiodensities were confirmed statistically in the present study, it seems likely that these sinus radiodensities develop due to stimulation from various odontogenic/non-odontogenic inflammatory conditions. Duce et al. [31] reviewed 28 cases of radiodensities in the maxillary sinus and reported that 16 patients had a history of tooth extractions and 21 were associated with sinus infections. Som et al. [29] evaluated 235 cases with very radiodense material within soft tissues of the paranasal sinuses due to various diseases using computed tomography and histopathology. The authors reported that solitary radiodense material is likely to be found in soft tissue masses of inflammatory origin, which corroborates findings in the present study that showed 17 out of 35 sinuses (48.6%) presenting with radiodensities also exhibiting reactive changes of the Schneiderian membrane.

This study has several important limitations, which are mostly based on its retrospective nature. First, only radiodensities that were incidentally observed in CBCT images were analyzed. Therefore, it is supposed that the included patients had no subjective symptoms in the maxillary sinuses analyzed, which is also highlighted by exclusion of patients with suspected sinus pathology. Second, the average age of the study population was relatively low, and the number of patients with loss of teeth in the posterior maxilla and with periodontal disease was also rather small. Third, the temporal relationship between the status of the sinus mucosa and the dentition, endodontic status, and periodontal pathology could not be recorded exactly due to the retrospective nature of the present study. It may be speculated that periodontal pathology leads to a localized or even more generalized swelling of the sinus mucosa, which then may result in ectopic calcification(s) that can be seen radiographically as radiodensities. Regarding the small sample size of the present study, the significant correlation between periodontal pathology and the presence of a radiodensity has to be interpreted with caution. Therefore, prospective studies taking into account these limitations are needed to confirm the findings presented.

Since CBCT has high spatial resolution, it is an effective tool for detection of radiodensities in the maxillary sinus. However, with the voxel size used in the present study (0.4 mm), there was some difficulty to judge the shape and the contact with the sinus wall for relatively small radiodensities. For these parameters, images with smaller voxel sizes would be more suitable [32]. Nevertheless, CBCTs with large FOVs were selected for this study as it was necessary to visualize both maxillary sinuses entirely according to the inclusion criteria.

Conclusions

Based on the findings of the retrospective analysis of 169 CBCT scans, the following conclusions can be made:

- Radiodensities in the maxillary sinus were observed in 16.6% of asymptomatic patients (10.4% of all sinuses analyzed/28 patients or 35 sinuses). Out of the 35 sinuses presenting with radiodensities, 17 (48.6%) were also exhibiting morphological changes of the Schneiderian membrane.
- Periodontal pathology in the posterior maxilla seems to be an influencing factor on the presence of sinus radiodensities. Nevertheless, the limited sample size of the present analysis warrants these findings to be interpreted with caution.
- Age and morphological changes of the sinus mucosa seem to be influencing factors on the shape of radiodensities.
- As incidentally detected radiodensities are most often diagnosed on the floor of the maxillary sinus, the clinical relevance of this finding for interventions such as apical surgery or sinus floor elevations should be evaluated in future studies.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study protocol was submitted to and approved by the local institutional review board (IRB) of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (approval number UW 17-462).

Informed consent For this type of study (retrospective study), formal consent is not required.

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