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ORIGINAL ARTICLE

Correlation of cone beam computed tomography (CBCT) findings in the maxillary sinus with dental diagnoses: a retrospective cross-sectional study

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Abstract This study was conducted to assess the coincidence of mucosal hyperplasia in the maxillary sinus and related clinical diagnoses of posterior maxillary teeth found in cone beam computed tomography (CBCT) scans. A total of 204 patients who underwent CBCT examinations between 2006 and 2008 were evaluated retrospectively. Clinical and CBCT findings were correlated using patient records. Absolute frequencies, odds ratios (OR), and 95% confidence intervals (95% CI) were calculated for statistical evaluations. There was a pronounced association between periodontitis and radiological signs of sinusitis. Basal mucosal wall thickening was more likely in patients with decayed and non-vital teeth compared to patients with sound teeth (OR=5.2; 95% CI=1.2–23.1). Basal mucosal wall thickening was also more likely than total mucosal thickening (OR=10.4; 95% CI=2.6–42.2). Patients with decayed and endodontically treated teeth were more likely to exhibit involvement of the basal wall (OR=9.2; 95% CI=3.3–25.2) than were patients with healthy teeth. CBCT examinations revealed a correlation between basal mucosal thickening in the maxillary sinus and decayed posterior maxillary teeth or periodontitis. Chronic symptoms involving the sinuses are one of the most common reasons for patients to consult physicians. One reason for chronic orofacial pain is the prevalence of undiagnosed sinus conditions.

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Introduction

Imaging of the maxillary sinus in dentistry has primarily been based on panoramic radiography, Water's projection, and intraoral radiography [1, 2]. Because of the complex anatomy of the oral and maxillofacial region, it is difficult to visualize important anatomical features due to the superimposition of structures when imaging maxillary sinuses that are close to molar areas [3, 4]. Radiographic findings for paranasal sinuses are usually assessed by otorhinolaryngologists using standard computed tomography [5, 6]. However, computed tomography places a higher risk on the patient due to high doses of radiation, and the use of CT in patient management has increased the overall radiation burden [7]. Cone beam computed tomography (CBCT) was first described in 1980 and was first applied to dentomaxillofacial radiology in 1998 [8–11]. This technique has obvious advantages, including lower radiation exposure, while providing adequate image quality [12].

Today, CBCT is often used by dentists and otolaryngologists to assess paranasal sinuses. The higher resolution and lower radiation doses represent the major advantages of CBCT in sinus diagnostics. However, extensive studies will be necessary to evaluate the incidence of mucosal thickening that is visible in CBCT images of the maxillary sinuses to relate these findings to the clinical pathologies of posterior maxillary teeth. These evaluations can help to identify correlations between tooth and sinus pathologies and to explain sinus issues with no nasal causative factors.

There only exist few reports of any correlation between clinical findings of posterior maxillary teeth and mucosal findings of the maxillary sinus. Therefore, the goal of this study was to evaluate the coincidence of mucosal findings in the maxillary sinus and the related dental diagnoses that were encountered in a dental clinic using CBCT.

Materials and methods

Definition of the study population

A total of 204 patients were included in this study (121 females and 83 males). The patient ages ranged between 7 and 82 years (median of 47.5 years; lower quartile, 36 years; upper quartile, 57 years). The indications for CBCT examinations were sinusitis, suspected aspergilloma, implant planning via image-guided surgery or oral surgery procedure planning (removal of impacted third molars), suspected tumor, ankylosis of anterior teeth, intra-osseous impaction of a foreign body, endodontic lesions, and searches for dental foci, oro-antral fistula, orthodontic planning, trauma, fractures, or chronic pain. The corresponding percentages are listed in Table 1.

A three-dimensional (3D) Accuitomo CBCT device (J Morita Corp., Kyoto, Japan) was used for patient examinations. The tube voltage ranged between 68 and 90 kV (median of 76 kV; lower quartile of 72 kV; and upper quartile of 83.5 kV). The tube current ranged between 2 and 5.5 mA (median of 4 mA; lower quartile of 3 mA; and upper quartile of 4.5 mA). Patients who underwent CBCT examinations between January 2006 and December 2008 were reevaluated using the patient management system VISIdent (BDV GmbH, Holzwickede, Germany). Stored CBCT datasets of patients were selected to include only those patients who underwent complete imaging of at least one maxillary sinus. A patient was only included in this study if his or her dataset showed a complete maxillary sinus, including the osteomeatal complex and entire maxillary floor (see Fig. 1). Indications for CBCT examination and the corresponding clinical diagnoses of the adjacent teeth (maxillary molars and premolars) were assessed on the basis of patient records. CBCT datasets were exported for evaluation by an independent observer to One Data Viewer Plus software (J Morita Corp., Kyoto, Japan) and were stored on a portable hard drive. These datasets were evaluated by a single observer (an oral surgeon with 3 years of experience in CBCT diagnosis). Mucosal thickness was assessed in coronal planes using the built-in caliper function of the One Data Viewer Plus software and was based on the maximum of the subjectively identified thickness of the floor, buccal wall, and roof of the maxillary sinus.

The findings of the osteomeatal complex were scored as "closed" if it was completely filled with mucosa, "small" if half of the ostium was filled with mucosa, and "open" if no mucosal thickening was visible. The thickness of the basal mucosa was classified as follows: "not visible," "visible" if it was between 0 and 3 mm in height and "thickened" if it was >3 mm in height. Wall involvement was classified as "basal wall involved" if mucosal thickening was isolated and found only on the maxillary sinus floor, "all walls involved" if mucosal thickening was found on every wall, and "complete opacification" if the entire sinus was filled with radiopaque masses. Radiological findings, ratings, and clinical findings as documented in patient records were transferred to an Excel spreadsheet (Excel 2007, Microsoft Cooperation, Redmond, USA).

Table 1 Indications for CBCT examinations listed according to patient records

Indication	Absolute frequency	Relative frequency in percent (%)
Sinusitis	37	18
Aspergilloma	5	2
Operation planning	68	33
Suspected tumor	8	4
Ankylosis	8	4
Intraosseus foreign body	5	2
Endodontic lesion	35	17
Focus search	8	4
Oro-antral fistula	1	0.5
Orthodontic	7	3
Trauma, fracture	7	3
Chronic pain	14	7
Not available	1	0.50

Fig. 1 Coronal slice of the maxillary sinus showing the osteomeatal complex and the palatal root of the first maxillary molar. Note the mucosal thickening on the sinus floor

Statistical methods

Statistical analyses were performed using SPSS 17.0 (SPSS Inc., Chicago IL, 2008) and SAS 9.2 (SAS Institute, Cary, NC, 2008) software programs. We computed the minima, maxima, medians, and quartiles for quantitative variables or absolute and relative frequencies for categorical data. The association of dental findings with the etiology of sinusitis (none/nasal causative factors/dental causative factors), severity of sinus problems (normal/visible/thickened or sinusitis), and wall involvement was investigated using nominal response logistic models.

We modeled the log odds as follows:

$$\log\left(\frac{\Pr(Y=i|x_1,\ldots x_p)}{\Pr(Y=0|x_1,\ldots x_p)}\right)=\beta_o+\sum_{i=1}^{p}\beta_i x_i,$$

where $Y=j$ denotes the event such that the outcome is in category j with 0 as the reference category (control). $\Pr(Y=j|x_1,\ldots x_p)$ is the probability that a person is in category i, given the explanatory variables have values $x_1,\ldots x_p$. β_{j0}, $\beta_{j1},\ldots$, and β_{jp} denotes the regression coefficients. The explanatory variables considered were gender (male/female), age group (less than 40, 40 to 49, 50 to 59, and 60 or higher), dental diagnoses, such as decayed and vital (DV) (yes/no), decayed and non-vital (DN) (yes/no), endodontically treated (ET) (yes/no), periodontitis (yes/no), and the absence of posterior teeth (AT) (yes/no).

Cases with unclear etiology (rhinogen/dentogen) were excluded from the etiology logistic regression. Cases with diagnoses that occurred in five or fewer patients were excluded from all logistic regression analyses. We present adjusted odds ratios (OR) with 95% confidence intervals (95% CI) and p values. The nature of this analysis is exploratory; therefore, all p values are descriptive.

Results

A total of 151 (74%) patients showed mucosal findings, such as visible or thickened basal mucosa. The results of the osteomeatal complex were as follows: 165 (81%) were classified as "open," 5 (2%) as "small", and 21 (10%) as "closed." A total of 13 (6%) could not be classified due to poor image quality. Related diagnoses of the posterior teeth, according to patient records, are listed in Table 2. Regarding the radiological findings, 67 (33%) patients showed findings of apical lucency, 25 (12%) had perforations of the vestibular wall, 22 (11%) had perforations of the maxillary sinus floor, and 1 (0.5%) had a perforation of the palatal wall. Overall, 56% of the patients showed basal mucosal thickening ($n=115$). The associations between the dental diagnoses and the scores for mucosal thickening, wall involvement, and classification of causative factors for sinus conditions are listed in Table 3 as absolute frequencies. Odds ratios with 95% confidence intervals and p values derived from the logistic regression models are shown in Table 4. Upon examination of the radiological classification (Table 4), men were more likely than women to have a thickened sinus mucosa (OR=2.3; 95% CI=1.0–5.3). Age was associated with the occurrence of neither visible nor thickened mucosa.

Dental diagnoses, such as DN, endodontically treated, and AT teeth, were all associated with both visible and thickened mucosa (suspected as pathological findings). For DV teeth, we only observed an association with thickened antral mucosa (OR=7.6; 95% 95% CI=1.7–34.4). There was a pronounced association between periodontitis and radiological classifications, such as thickened mucosa (suspected as pathological findings) (OR=31.8; 95% 95% CI=3.4–289.3).

Table 2 Diagnoses found for posterior maxillary teeth according to patient records; more than one diagnosis per patient was possible

Diagnosis posterior teeth	Frequency	Percent (%)
Normal	61	30
Decayed and vital	14	7
Decayed and non-vital	42	21
Endodontically treated	47	23
Periodontal pockets >3 mm	26	13
Edentulous	15	7
Radix relicta	1	0.5
Oro-antral fistula	2	1
Periimplantitis	5	2
Foreign body	1	0.5

Table 3 Absolute and relative frequency of the association between the radiological classification of maxillary sinus and wall involvement in mucosal thickening as related to the diagnoses found for the posterior teeth of the upper jaw

	Radiological classification						Wall involvement							
	Not visible		Visible		Thickened >3 mm		None		Basal only		All walls involved, incomplete opafication		All walls involved, complete opafication	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Gender														
Female	37	31	33	27	51	42	37	31	66	55	12	10	6	5
Male	16	19	15	18	52	63	16	19	49	59	13	16	5	6
Age group														
Under 40	14	24	13	22	32	54	14	24	29	49	11	19	5	8
40 to under 50	17	31	16	29	22	40	17	31	30	55	7	13	1	2
50 to under 60	12	25	13	27	23	48	12	25	30	63	4	8	2	4
60 and above	10	24	6	14	26	62	10	24	26	62	3	7	3	7
Dental diagnoses														
No pathology	36	59	9	15	16	26	36	59	13	21	8	13	4	7
Decayed and vital	3	21	1	7	10	71	3	21	9	64	2	14	–	–
Decayed and non-vital	4	10	10	24	28	67	4	10	28	67	7	17	3	7
Endodontically treated	7	15	16	34	24	51	7	15	32	68	5	11	3	6
Periodontitis	1	4	3	12	22	85	1	4	23	88	2	8	–	–
Absence of posterior teeth	3	20	6	40	6	40	3	20	11	73	1	7	–	–
Radix relicta	–	–	–	–	1	100	–	–	1	100	–	–	–	–
Oro-antral fistula	–	–	–	–	2	100	–	–	–	–	1	50	1	50
Peri-implantitis	–	–	2	40	3	60	–	–	4	80	1	20	–	–
Foreign body	–	–	1	100	–	–	–	–	1	100	–	–	–	–
Total	53	26	48	24	103	50	53	26	115	56	25	12	11	5

For the association of periodontitis and visible thickened mucosa, we observed an OR of 10.2 (95% CI=0.9–121.8). Wall involvement (Tables 3 and 4) was associated neither with gender nor age group. The involvement of all walls could only be associated with DN teeth. The involvement of basal wall only (isolated), however, could be associated with DN and ET teeth, periodontal disease, and AT teeth (see Table 4). Similarly, patients with decayed teeth and root fillings were more likely than patients with normal teeth to exhibit involvement of the basal wall and in patients with missing posterior teeth (see Table 4).

Discussion

In our study, CBCT examinations revealed a correlation between visible basal mucosa in the maxillary sinus and decayed posterior maxillary teeth or periodontitis. CBCT examinations revealed an increased incidence of mucosal findings in the maxillary sinus.

We found a pronounced association between periodontitis and radiological signs of thickened mucosa (see Table 4); the association between periodontitis and visible mucosa (see Table 4). Two likely explanations exist for the substantial mucosal thickening found in this study: the first is the definition that we used for mucosal thickening, and the second is the probable inability of CBCT to adequately display soft tissue. All associations had OR values well above 1, and the confidence intervals indicated that the associations were not simply due to chance. However, the thickness of normal mucosa (for normal maxillary sinuses) has been shown to be variable [13, 14]. Some studies have suggested that, on average, the normal thickness of healthy sinuses can be approximately 1 mm, with considerable variation among individuals [15]. Thus, it might be assumed that no sinus infection exists if an even mucosa thinner than 1 mm is visible on CBCT images of the maxillary sinus. Otherwise, it might be assumed that basal mucosal thickening is associated with dental infections. Janner et al. stated that the highest mean values for antral mucosa thickness (ranging from 2.16 to 3.11 mm) were found for the mucosa located in the midsagittal regions of the maxillary sinus, corresponding to the location of the posterior maxillary teeth. These authors enrolled all patients with edentulous posterior

Table 4 Associations among radiological classifications, wall involvement, age, gender, and diagnoses related to posterior teeth; these are the results of a multinomial logistic regression

Effect	Radiological classification	Category	Odds ratio (OR)	95% confidence limits for odds ratio	*p*	Wall involvement	Category	Odds ratio (OR)	95% confidence limits for odds ratio	*p*
Gender	Thickened >3 mm	Male vs female	2.3	1.0–5.3	0.0502	All walls involved	Male vs female	2.4	0.9–6.3	0.0755
Age		40 to under 50 vs under 40	0.4	0.1–1.1	0.0651		40 to under 50 vs under 40	0.3	0.1–1.2	0.0848
		50 to under 60 vs under 40	0.4	0.1–1.4	0.1549		50 to under 60 vs under	0.3	0.1–1.3	0.1229
		60 and above vs under 40	0.5	0.1–1.6	0.2484		60 and above vs under 40	0.4	0.1–1.5	0.1584
Decayed and vital		Yes vs no	7.6	1.7–34.4	0.0089		Yes vs no	2.6	0.4–18.8	0.3413
Decayed and non-vital		Yes vs no	16.4	4.7–57.8	<.0001		Yes vs no	10.4	2.6–42.2	0.001
endodontically treated		Yes vs no	7.8	2.7–22.3	0.0001		Yes vs no	4.2	1.2–14.7	0.024
Periodontitis		Yes vs no	31.8	3.5–289.3	0.0021		Yes vs no	6.4	0.5–87.3	0.1651
Absence of posterior teeth		Yes vs no	5.0	1.0–25.8	0.0523		Yes vs no	1.8	0.2–20.8	0.6235
Gender	visible	Male vs female	1.2	0.5–3.1	0.7124	Only basal wall involved	Male vs female	1.6	0.7–3.6	0.2669
		40 to under 50 vs under 40	0.7	0.2–2.0	0.4723		40 to under 50 vs under 40	0.5	0.2–1.5	0.2421
		50 to under 60 vs under 40	0.8	0.2–2.7	0.7486		50 to under 60 vs under	0.7	0.2–2.1	0.5175
		60 and above vs under 40	0.4	0.1–1.5	0.1547		60 and above vs under 40	0.5	0.2–1.7	0.2577
Decayed and vital		Yes vs no	1.0	0.1–10.5	0.987		Yes vs no	5.2	1.2–23.1	0.0299
Decayed and non-vital		Yes vs no	8.4	2.2–32.8	0.0022		Yes vs no	14.1	4.1–48.4	<.0001
endodontically treated		Yes vs no	7.0	2.3–21.1	0.0006		Yes vs no	9.2	3.3–25.2	<.0001
Periodontitis		Yes vs no	10.2	0.9–121.8	0.0658		Yes vs no	34.8	3.8–317.5	0.0017
Absence of posterior teeth		Yes vs no	7.1	1.4–34.8	0.016		Yes vs no	8.0	1.8–35.2	0.0058

The corresponding odds ratios, 95% confidence intervals for odds ratios (95% CI, OR), and *p* values (*p*) are listed according to the categories tested

maxilla who were scheduled for implant design using CBCT with a 3D Accuitomo device [16]. These selection criteria included patients with missing posterior teeth, for whom involvement of the basal wall with thickened mucosa was more. Ritter et al. assessed mucosal thickening by observer calibration in a retrospective study. They found a prevalence of 38.1% in a group of 1,029 patients (21.9% unilateral and 16.2% bilateral) [17]. The percentage of patients with sinus findings upon CBCT examinations in this study (74%) was higher than the percentage found by Logan and Brocklebank in occipitomental radiographs [18] and higher than the value found by Ritter et al. [17] or Panzera et al. [19] in CBCT images [17]. The major causes for these differences to our study might be due either to our pool of patients or the higher sensitivity of CBCT examinations for mucosal findings compared to plain radiography and the differential sensitivity of CBCT devices for soft tissues. Various CBCT devices have various sizes of flat panel detectors, and the geometry of large area detectors have a higher probability of being hit by scattered photons. Thus, the extent of the image-degrading effect of scattered radiation differs among CBCT machines. Scatter is well known to reduce soft tissue contrast [20, 21]. For instance, the 3D Accuitomo used in this study is associated with errors in visualizing soft tissues [22], mainly in the presence of beam-hardening materials. Thus, the inclusion and exclusion criteria for further studies of CBCT imaging abilities of antral findings must be reviewed, and patients with very large metallic resaturations might need to be excluded.

Chronic symptoms involving the sinuses are one of the most common reasons that patients consult physicians [13]. Undiagnosed sinus conditions, such as mucosal thickness, may be associated with chronic orofacial pain. An underlying hyperplasia of the sinus mucosa may contribute to the clinical symptoms leading to a diagnosis of atypical odontalgia or temporomandibular pain [18]. In many cases of reported chronic pain, endodontically treated teeth have no causative pathological processes that are visible to the examiner. This study indicates that CBCT images show possible hyper-reactive reactions of the basal mucosa in the maxillary sinuses of patients with root fillings, decayed non-vital posterior maxillary teeth, and periodontitis.

Conclusion

Undiagnosed hyperplasia of the sinus mucosa may contribute to the clinical symptoms leading to a diagnosis of atypical odontalgia or temporomandibular pain. CBCT examinations can reveal a correlation between visible basal mucosal findings in the maxillary sinus and decayed posterior maxillary teeth or periodontitis.

Conflicts of interest All authors disclose no actual or potential conflicts of interest, including any financial, personal, or other relationship with other people or organizations that could inappropriately influence this work.

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