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The Combination of Panoramic Imaging and Waters' Projection Contributes to the Diagnosis of Odontogenic Maxillary Sinusitis

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The purpose of this study was to evaluate the usefulness of adding Waters' projection to panoramic imaging compared with panoramic imaging or Waters' projection alone. Maxillary sinusitis in 106 patients (206 sinuses) was retrospectively assessed with panoramic imaging, Waters' projection, and computed tomography imaging by two oral radiologists. The diagnostic performance was assessed with computed tomography imaging as the gold standard. Receiver operating characteristic curves and area under the curve values were obtained. Inter- and intra-observer agreement was quantified using weighted kappa coefficients. Observer A performed the same procedure twice (A1 and A2 for the first and second observations, respectively). The accuracies of observers A1, B, and A2 with combination imaging were 0.699, 0.636, and 0.718, respectively. Their area under the curve values with combination imaging were 0.746, 0.640, and 0.771, respectively. Inter-observer agreement was good for Waters' projection (κ, 0.650), and poor for panoramic imaging (κ, 0281). Intra-observer agreement was good for Waters' projection (κ, 0.752), and moderate for panoramic imaging (κ, 0.597). Panoramic imaging was equivalent to Waters' projection for diagnosing maxillary sinusitis. Combination imaging comprising panoramic imaging and Waters' projection can contribute to the diagnosis of odontogenic maxillary sinusitis because of its high sensitivity.

INTRODUCTION

Odontogenic maxillary sinusitis is a common clinical problem in general dental practice. The close proximity of the maxillary roots to the sinus floor makes dental disease a probable cause (15, 21). In the diagnosis of maxillary sinusitis, it is important to distinguish between odontogenic and non-odontogenic causes because the treatment methods differ between the two (3, 16, 27). Odontogenic maxillary sinusitis may not be cured using standard otolaryngologic methods without first addressing the underlying dental cause. In our institution, we usually perform panoramic imaging and Waters' projection when a patient presents with symptoms characteristic of maxillary sinusitis, such as stuffy or running nose, headache, and swelling. These X-ray techniques can be used to assess the orofacial region including the paranasal sinus, upper jaw, and lower jaw. Panoramic imaging can be used to detect dental lesions, temporomandibular joint bone changes, and maxillary sinus opacity as well as dental caries, periapical lesions, and periodontal lesions that cause maxillary sinusitis (19). Waters' projection can detect sinus opacity and sinus bone conditions (23).

Computed tomography (CT) imaging and cone beam CT (CBCT) imaging are often used to diagnose lesions in the maxillary sinuses, especially in cases of progressing maxillary sinusitis caused by three-rooted teeth, thanks in part to the high spatial resolution potential of these methods. It may be difficult to recommend CT imaging from the perspectives of radiation exposure and health care cost in cases with mild symptoms or in follow-up cases (6, 8). Even though low-dose paranasal sinus CT imaging or CBCT imaging has been recommended in some studies, an optimal imaging protocol for odontogenic maxillary sinusitis has yet to be established (2, 7, 12-14, 25).

Numerous studies have investigated various modalities for maxillary sinusitis but there is relatively little research on the diagnostic utility of a combination of modalities for odontogenic maxillary sinusitis (1, 4, 10). To our knowledge, there are no studies comparing the diagnostic accuracy of panoramic imaging, Waters'

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projection, and a combination of the two (combination imaging) for odontogenic maxillary sinusitis. The concordance of panoramic imaging and Waters' projection between oral radiologists is therefore unknown.

The purpose of this study was to evaluate the usefulness of adding Waters' projection to panoramic imaging compared with panoramic imaging or Waters' projection alone. Here, we compare the ability of oral and maxillofacial radiologists to identify odontogenic maxillary sinusitis using panoramic imaging, Waters' projection, and combination imaging, with CT imaging used as the gold standard.

MATERIALS AND METHODS

Patients

This study protocol was approved by the Ethics Committee of Osaka Dental University (No. 111007). This retrospective study involved 106 patients (50 male, 56 female; mean age, 49 years; range, 17–82 years) with suspected maxillary sinusitis who underwent panoramic imaging, Waters' projection on the same day, and CT imaging within 2 days in our oral radiology department from December 2015 to May 2018. The criteria for a diagnosis of maxillary sinusitis were based on previous research: mucosal thickening and/or fluid collection in more than one-third of the maxillary sinus, including the sinus floor, on CT images (26). Additionally, detection of an odontogenic cause of sinusitis required apical/marginal periodontitis of the maxillary teeth, a fistula, mucosal thickening, and a sinus floor abnormality or defect on CT images. The diagnosis was odontogenic maxillary sinusitis in 53 patients based on CT images. Of the 53 patients with odontogenic maxillary sinusitis, 15 were bilateral cases (28.3%; 11 male, 4 female; 30 sinuses) and 38 were unilateral cases (71.6%; 16 male, 22 female; 38 sinuses). A total of 206 sinuses were evaluated. Diagnoses were odontogenic sinusitis for 68 sinuses and non-odontogenic sinusitis or no lesion for 138 sinuses. In this study, the right and left maxillary sinuses were evaluated as independent cases; six patients (six sinuses) were excluded because of the histopathological diagnosis of a tumor or cyst. The patient selection flow diagram is shown in Figure 1. Patients were selected from radiological information system records and therefore the history of chemotherapy or surgical treatment of the enrolled patients was unknown. Patients with mild clinical symptoms were included but no follow-up cases were included.

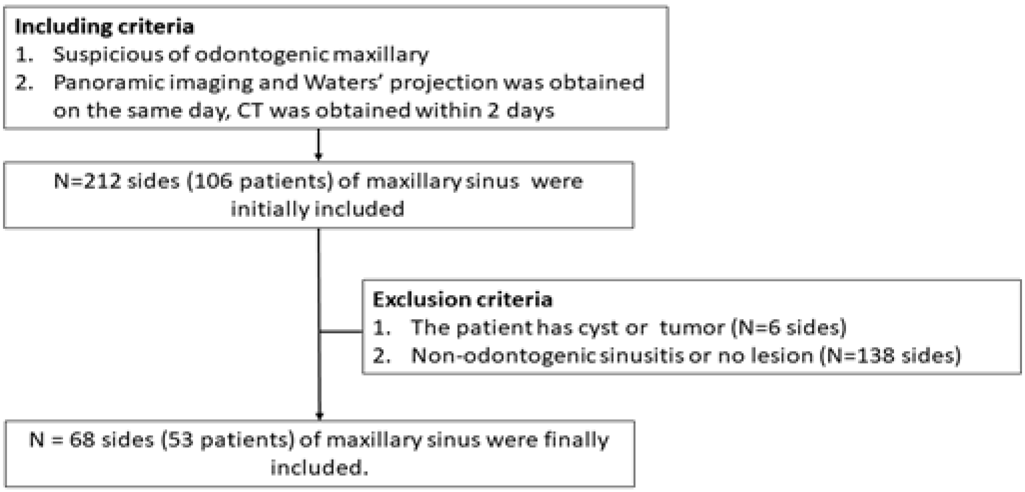

Figure 1. Patient selection flow diagram

Imaging Data Acquisition

All patients were examined using panoramic imaging, Waters' projection, and CT imaging according to routine clinical protocols. Panoramic imaging was performed using a Veraviewepocs 2D imager (73–76 kV, 10 mA, 8.0 s; Morita, Kyoto, Japan). Waters' projection was performed using a RADspeed Pro digital X-ray system (80 kV, 320 mA, 0.063 s; Shimadzu, Kyoto, Japan). CT images were obtained using a BrightSpeed Elite CT scanner (120 kV; GE Healthcare, Chicago, IL) using the following parameters: slice thickness, 0.75 mm; pitch and tube voltage, 0.625:1; field of view, 168 × 168 mm. The electric current was automatically optimized for the object thickness (maximum, 120 mA). The axial and coronal views of CT images were constructed using the multiplanar reconstruction mode. The observers adjusted the contrast, brightness, and window levels using the visualization software.

Image Analysis

Two oral/maxillofacial radiologists (observers A and B, with 7 and 15 years of experience, respectively), who were blinded to patient information, evaluated the 206 sinus images independently. Observer A performed the same procedure twice, with a month separating the two observations; A1 denotes the first observation, and A2 the second.

CT imaging was used as the gold standard for diagnosing odontogenic maxillary sinusitis because a pathological diagnosis could not be made except for cases in which the lesion was a cyst or a benign or malignant tumor. Mucosal thickening or soft tissue density > 3 mm within the maxillary sinuses without a dental cause was considered a sign of non-odontogenic maxillary sinusitis.

To diagnose sinus disease, the observers evaluated maxillary sinus opacity and bone condition on Waters' projection and dental lesions and maxillary sinus opacity on panoramic imaging. Combination imaging was defined as integrating the findings of both panoramic imaging and Waters' projection when making a diagnosis. Both observers evaluated the presence or absence of disease according to a 5-point scale: 1, absence of disease; 2, probable absence of disease; 3, unable to determine the presence or absence of disease; 4, probable presence of disease; and 5, presence of disease (17). The observers reviewed the images independently on the same monitor under equivalent examination conditions. They were blinded to the patient's information for the image they were reviewing, with the exception of a random identification number attached to each image.

Statistical Analysis

Statistical analysis was performed using R for Windows (version 3.5.1; R Core Team, 2018, Vienna, Austria) (20). The diagnostic significance of panoramic imaging, Waters' projection, and combination imaging for the assessment of odontogenic maxillary sinusitis was compared with that of CT imaging. Receiver operating characteristic (ROC) curves were drawn and area under the curve (AUC) values were calculated based on the results of the 5-point scale evaluation with a cutoff point. In accordance with the ROC curve cutoff points, the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of diagnosing odontogenic maxillary sinusitis were calculated. The accuracy of the diagnostic methods was classified according to AUC values: 0.9–1, high; 0.9–0.7, moderate; and 0.7–0.5, low. The χ^2 test was used to compare the AUC values between observation conditions and between observers. Values of $p < 0.05$ were considered statistically significant.

Inter- and intra-observer agreement was quantified by weighted kappa coefficients, which were interpreted in qualitative terms as follows: < 0.40, poor; 0.40–0.60, moderate; 0.60–0.80, good; and > 0.80, almost perfect agreement.

RESULTS

The diagnostic performance of panoramic imaging, Waters' projection, and combination imaging for each observer (A1, A2, and B) is shown in Table I, with CT imaging used as the gold standard. With CT imaging as the gold standard, the accuracy of observer A1 with panoramic imaging was 0.743; B, 0.680; and A2, 0.704. The accuracy of A1 with Waters' projection was 0.718; B, 0.670; and A2, 0.718. The accuracy of observer A1 with combination imaging was 0.699; B, 0.636; and A1, 0.694. The AUC of observer A1 with panoramic imaging was 0.765 (moderate); B, 0.637 (low); and A2, 0.776 (moderate). The AUC of observer A1 with Waters' projection was 0.721 (moderate); B, 0.626 (low); and A2, 0.733 (moderate). The AUC of observer A1 with combination imaging was 0.746 (moderate); B, 0.640 (low); and A2, 0.771 (moderate). The results of the comparison of AUC values between observers by observation condition and between observation conditions by the observer are shown in Table II. There were significant differences between A2 and B using panoramic imaging as well as between A1 and B and between A2 and B using Waters' projection and combination imaging.

Table I. Diagnostic performance of each observer for maxillary sinusitis

		Sensitivity	Specificity	PPV	NPV	Accuracy
Panoramic imaging	ObserverA1	0.794	0.717	0.581	0.876	0.743
	ObserverB	0.529	0.754	0.514	0.765	0.680
	ObserverA2	0.779	0.667	0.535	0.860	0.704
Waters' projection	ObserverA1	0.691	0.732	0.560	0.828	0.718
	ObserverB	0.456	0.775	0.500	0.743	0.670
	ObserverA2	0.691	0.732	0.560	0.828	0.718
Combination	ObserverA1	0.794	0.652	0.529	0.865	0.699
	ObserverB	0.618	0.645	0.462	0.774	0.636
	ObserverA2	0.809	0.638	0.524	0.871	0.694

Combination: Panoramic imaging and Waters' projection, PPV: positive predictive value, NPV: negative predictive value

The inter- and intra-observer variability is shown in Table III. Inter-observer agreement was good for Waters’ projection (κ, 0.650), and poor for panoramic imaging (κ, 0281). Intra-observer agreement was good for Waters’ projection (κ, 0.752), and moderate for panoramic imaging (κ, 0.597). Examples of bilateral and unilateral odontogenic maxillary sinusitis for each modality are shown in Figures 2 and 3, respectively.

Table II. Combination, panoramic imaging, and Waters' projection

Condituions of interpretation		$\chi 2$ test	
Panoramic imaging	ObserverA1 (AUC: 0.765) *vs* ObserverB (AUC: 0.637)	p = 0.0789	
	ObserverA2 (AUC: 0.776) *vs* ObserverB (AUC: 0.637)	p = 0.00230	*
	ObserverA1 (AUC: 0.765) *vs* ObserverA2 (AUC: 0.776)	p = 0.702	
Waters' projection	ObserverA1 (AUC: 0.721) *vs* ObserverB (AUC: 0.626)	p = 0.00257	*
	ObserverA2 (AUC: 0.733) *vs* ObserverB (AUC: 0.626)	p = 0.000982	*
	ObserverA1 (AUC: 0.721) *vs* ObserverA2 (AUC: 0.733)	p = 0.711	
Combination	ObserverA1 (AUC: 0.746) *vs* ObserverB (AUC: 0.640)	p = 0.00649	*
	ObserverA2 (AUC: 0.771) *vs* ObserverB (AUC: 0.640)	p = 0.000148	*
	ObserverA1 (AUC: 0.746) *vs* ObserverA2 (AUC: 0.771)	p = 0.351	
ObserverA1	Panoramic imaging (AUC: 0.765) *vs* Waters' projection (AUC: 0.721)	p = 0.0789	
ObserverB	Panoramic imaging (AUC: 0.637) *vs* Waters' projection (AUC: 0.626)	p = 0.774	
ObserverA2	Panoramic imaging (AUC: 0.776) *vs* Waters' projection (AUC: 0.733)	p = 0.0851	

AUC; area under the curve, Combination; panoramic imaging and Waters’ projection * $p < 0.05$

Table III. Weighted κ score of each examination

	Waters' projection	Panoramic imaging
Inter-observer agreement(A1-B)	0.650 (good)	0.281 (low)
Intra-observer agreement(A1-A2)	0.752 (good)	0.597 (moderate)

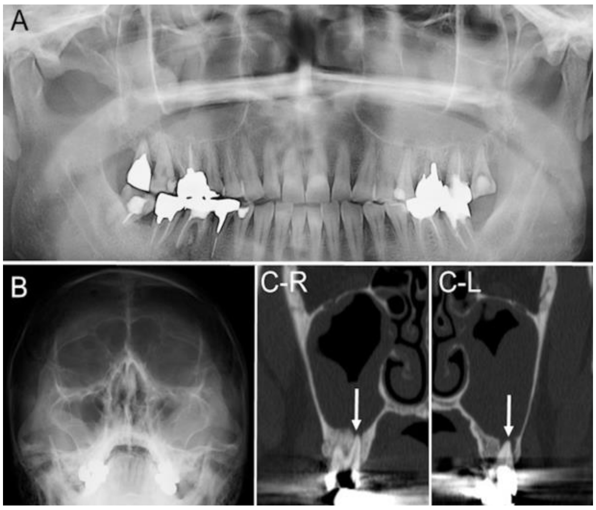

Figure 2. Bilateral odontogenic maxillary sinusitis.
(A) Periapical lesions of the bilateral maxillary third molars and the left maxillary second premolar and second molar. The maxillary sinuses on both sides show radiopacity on panoramic imaging. (B) The maxillary sinuses on both sides show radiopacity on Waters’ projection. (C) Bone algorithm computed tomography coronal image showing periapical lesions of the maxillary right third molar and left second molar (arrows). Soft tissue density can be seen in the maxillary sinuses on both sides.

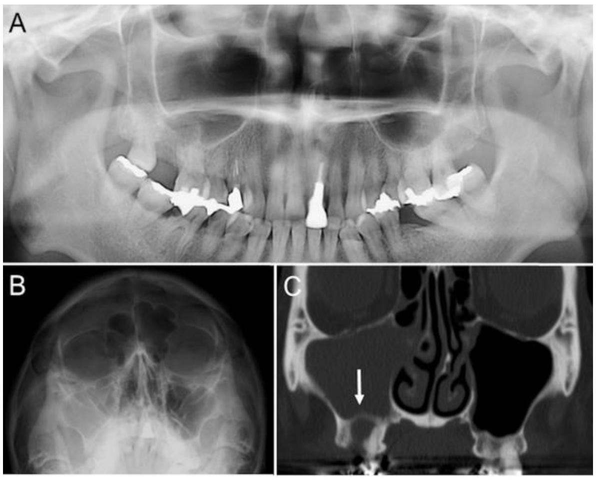

Figure 3. Unilateral odontogenic maxillary sinusitis.
(A) Periapical lesion of the extracted right second molar on panoramic imaging. (B) The right maxillary sinus shows radiopacity on Waters' projection. (C) Bone algorithm computed tomography coronal image showing elevation of the maxillary sinus floor (arrow). Soft tissue density can be seen in the right maxillary sinus.

DISCUSSION

Panoramic imaging provides a tomographic image with broad coverage of hard and soft tissues in the orofacial region, including the maxilla, mandible, dentition, and adjacent structures. This technique can be used to detect dental lesions in the jaws. It exposes patients to a lower radiation dose, costs less, and is more readily available than CT imaging. The posterior sinus wall and pterygopalatine fossa are visualized on panoramic imaging; bone destruction or expansion of these areas is indicative of the presence of disease (11). It is our understanding that most radiologists are not familiar with panoramic imaging. Dentists and otolaryngologists who have expertise in the dental field are capable of interpreting panoramic images.

Although Waters' projection is commonly used as a screening test for maxillary sinusitis, we confirmed that the accuracy and AUC of Waters' projection are nearly the same as those of panoramic imaging (Tables I and II). These findings are consistent with those of other studies (4, 10) and indicate that the accuracy of Waters' projection is equivalent to that of panoramic imaging for diagnosing maxillary sinusitis.

The sensitivity and specificity of maxillary sinusitis on CT imaging for experienced oral and maxillofacial radiologists are 90%–95% (22). The discrepancy in diagnostic ability between CT imaging and other plain X-ray techniques is attributable to the following three reasons. First, a clear sinus on a Waters' projection does not consistently rule out maxillary mucosal inflammatory disease (1, 4, 10). It is difficult to detect the opacity of the sinus floor when mucosal thickening is limited on the sinus floor because it is overlapped by the maxillary bone on the Waters' projection image (9, 24). Mucus thickening depicted as soft tissue density on plain X-ray may have opacity comparable to air, not bone. Second, it is challenging to detect dental conditions on Waters' projection images. Although large radicular cysts or significant changes in maxillary opacity at the base of the maxillary sinus can be identified, apical and periodontal lesions may not be detected by Waters' projection (Figure 2). Third, reproducibility is lower with Waters' projection than with CT imaging. These conventional techniques are dependent on the patient's head position and the radiological equipment used by the technicians. Conversely, CT imaging is less dependent on head position and can be used to create a three-dimensional image.

Our findings showed that Waters' projection was more reliable than panoramic imaging in terms of inter- and intra-observer reproducibility. Both inter- and intra-observer reproducibility of Waters' projection (good) was superior to that of panoramic imaging (low and moderate, respectively). These findings also suggest that Waters' projection is more reliable than panoramic imaging for assessing maxillary sinusitis in follow-up cases.

Panoramic imaging can detect the radiolucency of apical and periodontal lesions or mucosal thickening of the maxillary sinus floor and posterior wall. However, it would be difficult to compare the opacity of the maxillary sinus in follow-up cases because of its low inter- and moderate intra-observer agreement. There are several reasons for this. First, 30 of 68 cases (44%) had bilateral odontogenic maxillary sinusitis. When there are sinus opacities on both sides, a diagnosis of odontogenic maxillary sinusitis is challenging with panoramic imaging (Figure 2) (17). Second, there are soft tissue images, ghost images, and normal variances on panoramic imaging (5, 18). The inferior turbinates and hard palate are overlapped by the maxillary sinus (Figure 3).

The advantage of panoramic imaging is its relatively high rate of detecting apical and periodontal lesions. The infected teeth must be identified to choose the correct treatment. Because of its resolution, panoramic imaging is less reliable than intra-oral imaging and CBCT imaging but is superior to Waters' projection or other plain X-ray techniques (5). Panoramic imaging exposes patients to lower radiation than CT imaging. The radiation dose by sinus CT imaging is much higher than the combination of panoramic imaging and Waters' projection, especially to the lens of the eyes. In this respect, repeated CT imaging may not be recommended for diagnosing odontogenic maxillary sinusitis for the follow-up cases. Considering the advantages and disadvantages of panoramic imaging and Waters' projection, combining the two achieves higher sensitivity and negative predictive values compared with panoramic imaging or Waters' projection alone. Panoramic imaging is used as a screening examination in dentistry and has high sensitivity. Conversely, Waters' projection is considered a relatively high specificity examination for maxillary sinusitis. Therefore, combination imaging can be useful for assessing odontogenic maxillary sinusitis because of its high sensitivity, which outweighs its relatively low accuracy.

The difference in AUC between observers A2 and B using panoramic imaging and between A1 and B and between A2 and B using Waters' projection or combination imaging suggests that the diagnostic accuracy of Waters' projection and combination imaging may differ more according to the observer when compared with panoramic imaging alone in the diagnosis of odontogenic maxillary sinusitis.

This study had some limitations that should be addressed. The first concern is the patient population. Of the 106 patients registered, 53 (68 sinuses) were diagnosed as having odontogenic maxillary sinusitis; this number of sinuses is insufficient for a retrospective study, and thus a larger-scale prospective study is needed. Second, no histopathological evidence was used in the diagnosis of odontogenic maxillary sinusitis because maxillary sinusitis is usually diagnosed clinically. Third, one observer assessed the intra-observer agreement measure twice, and the other observer assessed the measure of inter-observer agreement in this study. Although it is desirable to implement it with a large number of radiologists, only two oral and maxillofacial radiologists were able to participate in this examination. Accordingly, the sensitivity of each technique for diagnosis might not be sufficiently reliable. For these reasons, further studies are needed to assess the usefulness of plain X-rays for diagnosing odontogenic maxillary sinusitis.

In conclusion, this study examined the usefulness of the addition of Waters' projection to panoramic imaging compared with panoramic imaging or Waters' projection alone. The results showed that panoramic imaging was equivalent to Waters' projection for diagnosing odontogenic maxillary sinusitis. Additionally, a combination of panoramic imaging and Waters' projection can contribute to the diagnosis of odontogenic maxillary sinusitis. Because the two techniques are complementary, the use of both techniques allows either to be considered more reasonable in diagnosing odontogenic maxillary sinusitis.

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CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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