Automated detection of abnormalities in paranasal sinus on dental panoramic radiographs by using contralateral subtraction technique based on mandible contour

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ABSTRACT

Inflammation in paranasal sinus sometimes becomes chronic to take long terms for the treatment. The finding is important for the early treatment, but general dentists may not recognize the findings because they focus on teeth treatments. The purpose of this study was to develop a computer-aided detection (CAD) system for the inflammation in paranasal sinus on dental panoramic radiographs (DPRs) by using the mandible contour and to demonstrate the potential usefulness of the CAD system by means of receiver operating characteristic analysis. The detection scheme consists of 3 steps: 1) Contour extraction of mandible, 2) Contralateral subtraction, and 3) Automated detection. The Canny operator and active contour model were applied to extract the edge at the first step. At the subtraction step, the right region of the extracted contour image was flipped to compare with the left region. Mutual information between two selected regions was obtained to estimate the shift parameters of image registration. The subtraction images were generated based on the shift parameter. Rectangle regions of left and right paranasal sinus on the subtraction image were determined based on the size of mandible. The abnormal side of the regions was determined by taking the difference between the averages of each region. Thirteen readers were responded to all cases without and with the automated results. The averaged AUC of all readers was increased from 0.68 to 0.73 with statistical significance ($p=0.042$) when the automated detection results were provided. In conclusion, the automated detection method based on contralateral subtraction technique improves readers' interpretation performance of inflammation in paranasal sinus on DPRs.

Keywords: CAD, torso FDG-PET, temporal subtraction, statistical image analysis

1. INTRODUCTION

Inflammation in paranasal sinus sometimes becomes chronic to take long terms for the treatment. Image diagnosis of the inflammation on dental panoramic radiograms (DPRs) is not difficult for oral and head/neck radiologists, however general dentists may not recognize the findings because they focus on teeth treatments. We have been developing a computer-aided detection (CAD) method of the inflammation on DPRs by using a contralateral subtraction method by comparing the densities of left and right paranasal sinus. The patient positioning in imaging DPR may affect the detection performance on subtraction images. To reduce the performance deterioration because of the registration error on the contralateral subtraction, symmetric anatomical structures around the paranasal sinus such as mandible contours could be available as landmarks to register. The purpose of this study was to develop a contralateral-subtraction based CAD system for the inflammation in paranasal sinus on DPRs by using anatomical information of the automatically determined mandible contour and also to demonstrate the potential usefulness of the CAD system by means of receiver

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operating characteristic (ROC) analysis with sequential tests. We employed the contour of mandible extracted as the anatomical structure for the analysis of osteoporosis as the anatomical structure [1].

The subtraction technique was widely used for chest image diagnosis. Fleming mentioned the possibilities of the technique for chest X-ray images in 1979 [2]. Li, et al. reported a computerized scheme for nodule detection on chest X-ray image [3, 4]. Tsukuda et al. reported the usefulness of the contralateral subtraction approach for detecting lung nodules on chest radiographs [5]. Nagashima et al. applied the idea to computer-aided detection of cerebral infarctions in brain CT [6]. The contralateral subtraction technique contains many aspects of image registration and pixel subtraction. We applied the technique to DPRs because the maxillofacial skeleton supported the symmetrical structures on the images.

2. METHODS AND MATERIALS

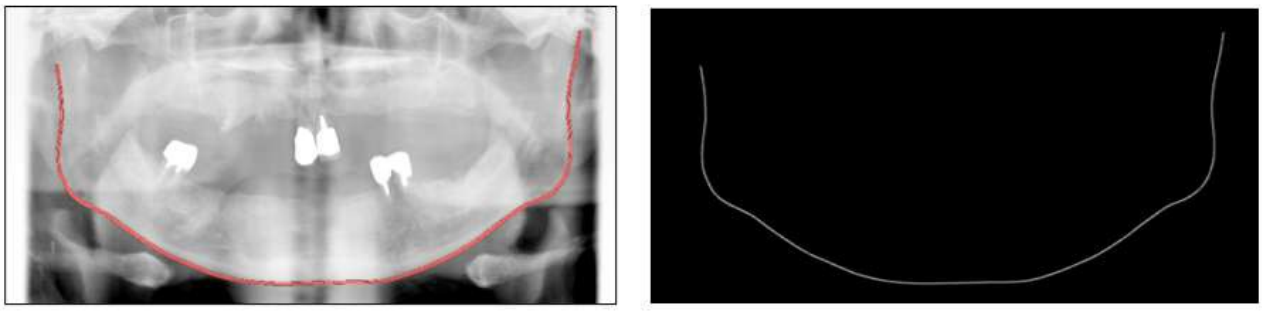
2.1 Detection Scheme

The detection scheme consists of 3 steps: 1) Contour extraction of mandible, 2) Contralateral subtraction, and 3) Automated detection. The Canny operator was applied to extract the edge at the first step. A mask image specifying seven regions was created from the training data (100 cases) with manual mandibular contours to identify an initial mandibular contour from the edge image. The inferior border of the mandibular bone was detected by use of an active contour method based on the initial contour. Figure 1 shows the determined contour based on the technique already reported in paper [1]. The regions of both mandible ends were selected on the DPRs to compare with each of the other sides. Figure 2 shows the extracted two regions of right and left mandible ends. By changing the locations of filliped image of left mandible ROI on right ROI as shown on Figure 3, mutual information was obtained in each location. The most agreement location was determined by the value of the mutual information. The shift value to agree the two ROIs was used to subtract two images of original and right-to-left flipped image.

At the subtraction step, the right region was flipped to compare with the left region. Mutual information between two contours on the two selected regions was obtained to estimate the shift parameters of image registration. The subtraction images were determined based on the shift parameter. Figure 4 shows an example of original image and horizontally flipped one of the original image with the shift parameter determined the previous step. The automated detection was performed on the subtraction image. The subtraction image was obtained by the taking the pixel value on original image from flipped one. Rectangular regions of left and right paranasal sinus on the subtraction image were determined based on the size of mandible. Figure 5 shows the ROIs for the detection step. The abnormal side of the regions was determined by taking the difference between the averages of pixel values in each region.

2.2 Database

We employed 2 databases of DB1 and DB2 collected from two different hospitals to estimate the detection performance. DB1 and DB2 consist of 48 normal and 34 abnormal cases, and 34 normal and 34 abnormal cases, respectively. All of the normal cases were verified by using head CT scans.



(a) (b)

Figure 1. Example of contour extraction.

(a) Extracted mandible contour imposed on DPR image. (b) Extracted contour for the registration.

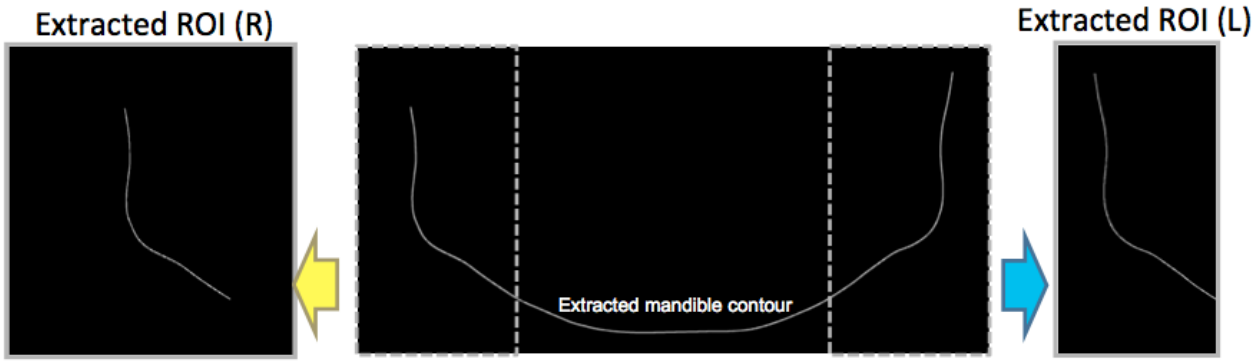


Figure 2. Extracted ROIs of right and left mandibular areas.

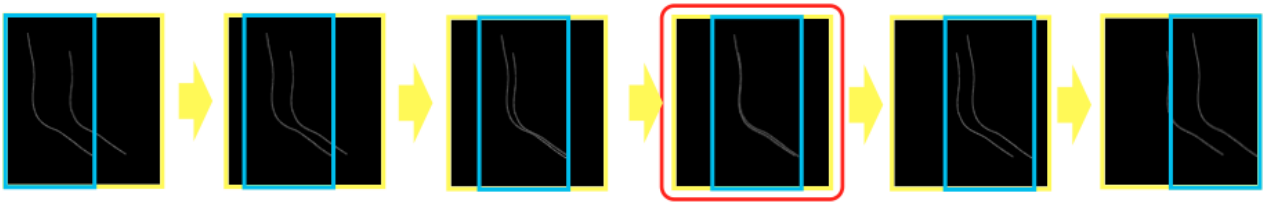


Figure 3. Example of shift value determination based on mutual information.

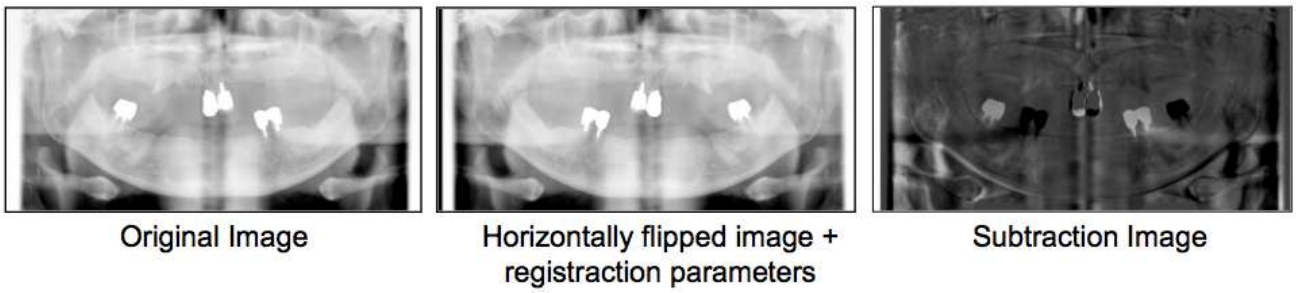


Figure 4. Example of original image and horizontally flipped image registered to original image. The subtraction image was obtained by the taking the pixel value on original image from flipped one.

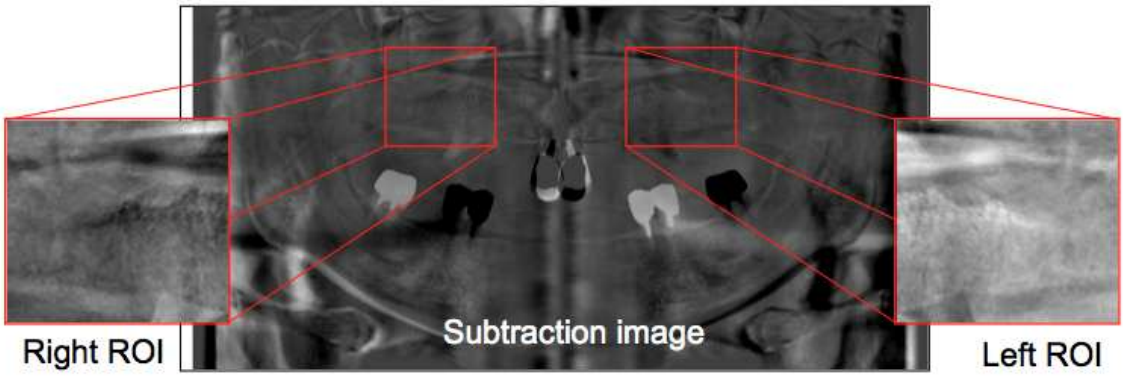


Figure 5. Right and left ROIs for the detection step. The averaged pixel values in the two ROIs were compared each other.

2.3 Performance evaluation without/with computer outputs

An observer performance study was designed to measure the change of interpretation results when the automated detection results were provided to readers. 13 readers of nine residents and four students in a dental college took part in the observer performance study. The sequential test method was employed in the observer performance study. Readers were asked to respond to all DPRs with confidence levels for the existence of abnormal regions on paranasal sinus if they recognized abnormalities on left or right.

3. RESULT

The automated detection performance of the CAD system itself was evaluated at first by three measurements of true-positive fraction (TPF), true-negative fraction (TNF), and the area under the ROC curves (AUC). The (TPFs, TNFs, AUCs) on DB1 and DB2 were (76%, 56%, 0.74) and (76%, 32%, 0.75), respectively. We founded by visual assessments that 145 of 150 images were correctly registered in the process of contralateral subtraction.

Thirteen readers responded to all cases without and with the automated results. Table 1 shows the AUCs without and with computer outputs. The averaged AUCs for all readers were increased from 0.69 to 0.73 with statistical significance (p=0.032). The averaged AUCs for residents and trainees were increased from 0.70 to 0.74 (p=0.278) and 0.67 to 0.73 (p=0.413), respectively, when the automated detection results were provided. The AUCs of readers R5, R7, and R9 were decreased without statistical significance when they used the computer results. The statistical significances of intra-observer were confirmed on only three readers of R2, R3, and R4.

Figure 6 shows the averaged ROC curves of 13 readers with and without computer output. Figure 7 shows the example of beneficial and detrimental cases during the observer performance study. Fig.7 (a) shows a beneficial case for 10 of 13 readers. They increased their confidence levels after the computer detection output and the subtraction image were provided for the interpretation. Fig. 7 (b) shows a detrimental case for 12 of 13 readers. The normal paranasal region on the right side was confirmed by CT scan, but the computer marked the white region as false positive sign. They increased their confidence levels because of the false positive mark.

Table 1. The AUC changes of 13 readers.

		AUC Without Comp.	With Comp.	P-value (* P<0.05)
Resident	**R1**	0.69	0.67	0.5426
	R2	0.79	0.83	0.0023 *
	R3	0.63	0.77	0.0272 *
	R4	0.60	0.73	0.0270 *
	R5	0.76	0.69	0.1812
	R6	0.70	0.78	0.1627
	R7	0.80	0.76	0.5037
	R8	0.61	0.71	0.1910
	R9	0.65	0.63	0.8607
Average		**0.69**	**0.73**	**0.185**
Student	**R10**	0.57	0.68	0.1107
	R11	0.77	0.80	0.4382
	R12	0.60	0.69	0.1461
	R13	0.71	0.71	0.9552
Average		**0.66**	**0.72**	**0.111**
Total		**0.68**	**0.73**	**0.042 ***

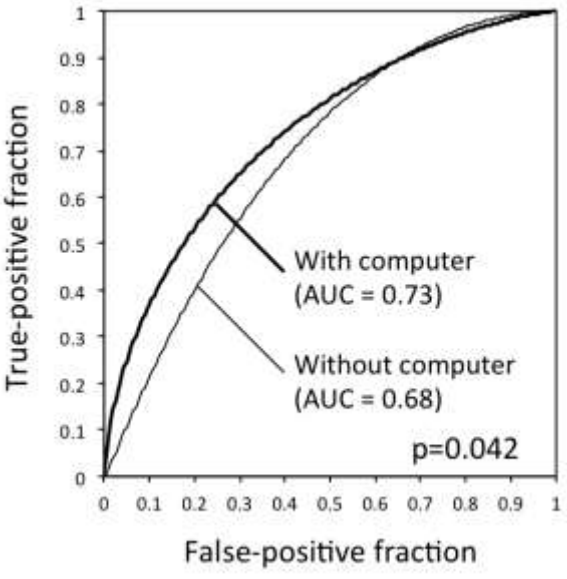
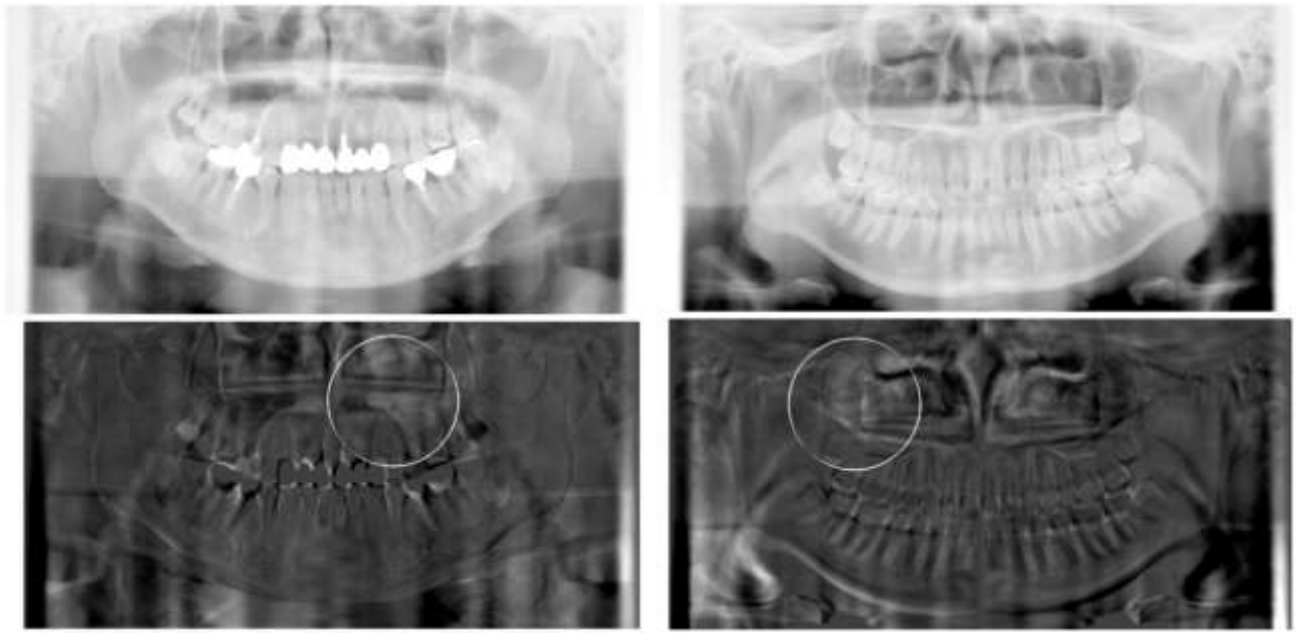


Figure 6. Averaged ROC curves of 13 readers.



(a) (b)

Figure 7. Examples of computer output and subtraction image of abnormal and normal cases. (a) Abnormal case with left side paranasal regions. The computer output was beneficial for 10 of 13 readers. (b) Normal case verified by CT scans. The computer output was detrimental for 12 of 13 readers because of the false positive mark.

4. DISCUSSIONS

The detection performance was not depending on the accuracy of the contralateral subtraction results in this study because over 95% images were registered correctly. The determination of paranasal sinus may not be appropriate for the comparison of left and right densities. Therefore, automated recognition techniques of other anatomical structures are required to determine the two regions around nose.

The increment of AUC can be compared with our previous results [7]. Automated detection method in our previous scheme was based on a contralateral subtraction technique with image registrations of tooth regions only. When the automated detection results were provided, the averaged AUC of residents was decreased from 0.78 to 0.75 with no statistical significance, while the averaged sensitivity of the residents was increased from 66% to 73%. We believe that the new contralateral subtraction method based on the contour mandible was effective to improve the changes of readers' interpretation results.

Readers practiced a training set before the observer performance study with an explanation of the concept of CAD. However, the detection performance of the computer was not informed to the readers in order to avoid the surplus bias during the interpretations. Therefore, the readers may have recognized that the computer showed very high performance for the detection of abnormalities, although the actual detection performance of the computer results was 0.74 of AUC. The false-positive marks on computer results may have affected the readers' interpretation results. Further data collection and observer performance study are required to validate the automated detection method.

5. CONCLUSIONS

The automated detection method based on contralateral subtraction technique improves readers' interpretation performance of inflammation in paranasal sinus on dental panoramic radiograms.

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