

# Automated scheme for measuring mandibular cortical thickness on dental panoramic radiographs for osteoporosis screening

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## ABSTRACT

Findings of dental panoramic radiographs (DPRs) have shown that the mandibular cortical thickness (MCT) was significantly correlated with osteoporosis. Identifying asymptomatic patients with osteoporosis through dental examinations may bring a supplemental benefit for the patients. However, most of the DPRs are used for only diagnosing dental conditions by dentists in their routine clinical work. The aim of this study was to develop a computer-aided diagnosis scheme that automatically measures MCT to assist dentists in screening osteoporosis. First, the inferior border of mandibular bone was detected by use of an active contour method. Second, the locations of mental foramina were estimated on the basis of the inferior border of mandibular bone. Finally, MCT was measured on the basis of the grayscale profile analysis. One hundred DPRs were used to evaluate our proposed scheme. Experimental results showed that the sensitivity and specificity for identifying osteoporotic patients were 92.6 % and 100 %, respectively. We conducted multiclinic trials, in which 223 cases have been obtained and processed in about a month. Our scheme succeeded in detecting all cases of suspected osteoporosis. Therefore, our scheme may have a potential to identify osteoporotic patients at an early stage.

**Keywords:** Osteoporosis, Dental panoramic radiography, Computer-aided diagnosis, Mandibular cortical thickness, Active contour method, Grayscale profile

## 1. INTRODUCTION

Seventy-five million or more patients are suffering from osteoporotic diseases all over the world. Osteoporotic fractures represent a huge public health burden and incremental medical costs. Mandibular cortical thickness (MCT) on dental panoramic radiograph (DPR) was found to be significantly correlated with bone mineral density in the hip, lumbar spine and foramen, so that the MCT measurement is effective for osteoporosis screening [1]. DPRs are used to examine dental diseases in dental clinics over the world. Especially in Japan, more than 10 million DPRs are taken annually in dental clinics [2]. Identifying asymptomatic patients with osteoporosis through dental examinations may bring a supplemental benefit for the patients. However, most DPRs were used for only diagnosing dental conditions by dentists in their routine clinical work. Computer-aided diagnosis (CAD) system that measures MCT on DPRs quantitatively may be useful for dentists to identify asymptomatic patients with osteoporosis at an early stage. Therefore, we have proposed a new screening pathway by cooperation of dentists and the CAD system [3-5]. Dentists send the images to CAD system as an additional task in their routine clinical work. Then, our CAD system automatically runs the image analysis and the resulted images and reports are finally sent to the dentists. If any pathologic signs are detected, CAD alerts the dentists. After that, dentists inform patients of the possible risks for systemic diseases. If the patient desires, the dentist will refer to the medical clinic. High performance of our CAD system is essential to the success of this screening pathway. For that reason, in this study, we designed a new computerized scheme for MCT based on the active contour method on DPR, and evaluated its performance in clinical trials and experiments by using our test data.

## 2. METHODS

The overview of our proposed method is illustrated in Fig. 1. Our proposed scheme consists of the five steps. Canny edge detector and active contour method were used to extract the mandibular contour in the first (Step 1) and the second step (Step 2), respectively [6]. Positions of mental foramina, which exist both on left and right sides, were estimated

automatically on the basis of the result from the mandible contour extraction in the third step (Step 3), and the grayscale profiles in a direction perpendicular to the extracted mandibular contour were obtained at both sides separately in the fourth step (Step 4). Finally, MCTs on the both sides were determined by the analysis of the grayscale profiles (Step 5). The details of our proposed scheme are described as follows:

First, the edges on original image were detected by use of the Canny edge detector. A mask image specifying 7 regions was created from the training data (100 cases) with manual mandibular contours to identify an initial mandibular contour from the edge image (Fig. 2). In the second step, the inferior border of the mandibular bone was detected by use of an active contour method based on the initial contour. In the active contour method, the image similar to the edge image in Step 1 was selected from the training data of the mandibular contours. Function of the active contour method is defined as follows:

$$E_{snake} = E_{int}(v) + E_{image}(v) \quad (1)$$

$$E_{int} = \frac{1}{2} \int_0^1 \left\{ \alpha(s) \left| \frac{\partial v}{\partial s} \right|^2 + \beta(s) \left| \frac{\partial^2 v}{\partial s^2} \right| \right\} ds \quad (2)$$

$$E_{image} = \frac{1}{2} \int_0^1 P(v(s)) ds \quad (3)$$

$$P(x,y) = -\gamma \text{dist}(\text{mask}([G_\sigma \otimes I(x,y)])) \quad (4)$$

where  $E_{snake}$ ,  $E_{int}$  and  $E_{image}$  are energy functions, and  $\alpha$ ,  $\beta$  and  $\gamma$  are the weighting parameters. Closed curve defines  $v(s) = (x(s), y(s))$ ,  $s \in [0,1]$ .  $P$ ,  $G_\sigma$ ,  $\text{dist}$ ,  $\text{mask}$  and  $I$  represent the probability, Gaussian filter, pixel value of the Euclidean distance transformed image of the edge component in Step 1, identification of the mandibular contour by use of the mask image and original image, respectively. Usually, gradient image is used to calculate the value of  $E_{image}$ . However, many edges are detected on DPRs not related to mandibular contour. Therefore, pixel values of the Euclidean distance transformed image, instead of a gradient image, were used for  $E_{image}$  as shown in Fig. 3. The positions of mental foramina were estimated on the basis of the mandibular contour in the third step. In the fourth step, the line perpendicular to the mandibular contour was obtained by use of the least squares method. A total of 20 lines were obtained by the same method around the each measuring point. Finally, MCT was determined on the basis of the grayscale profile on the line. Results of the MCT measurement are shown in Fig. 5.

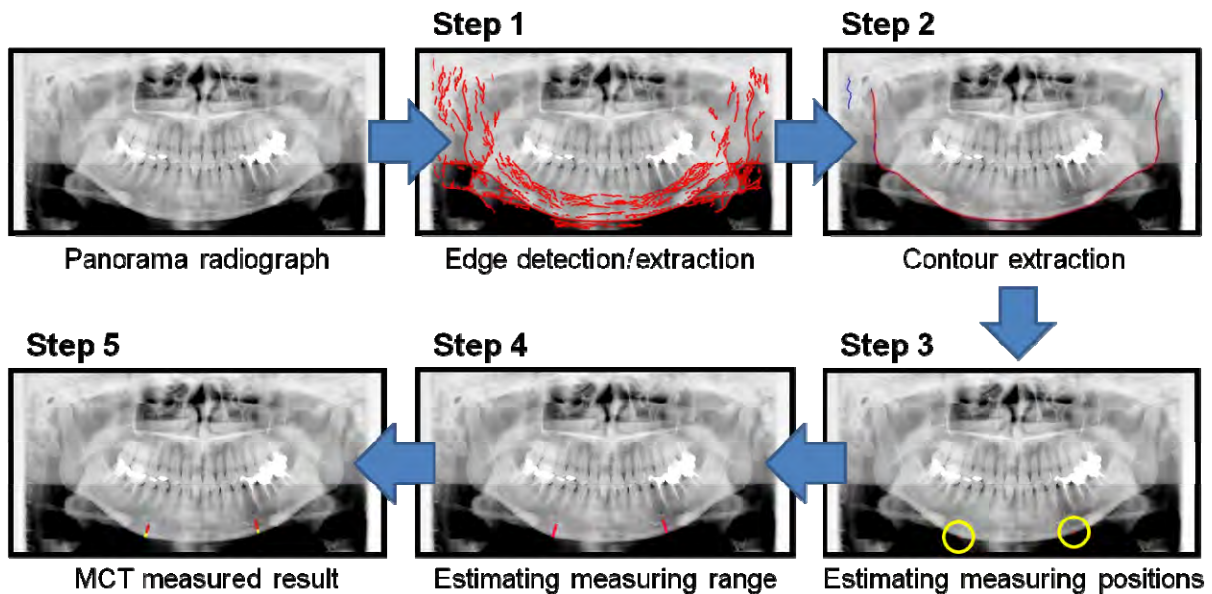
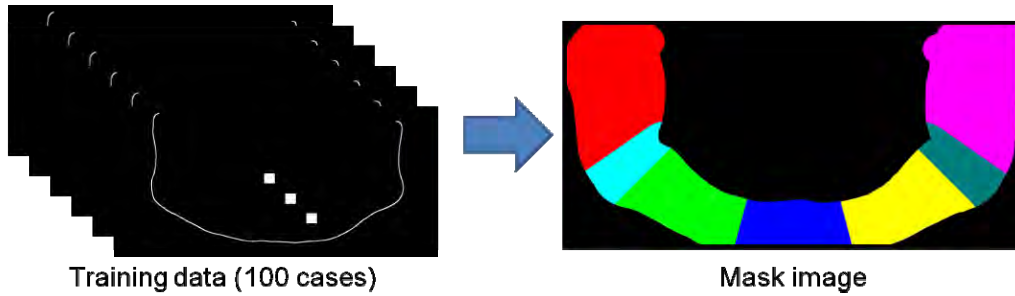
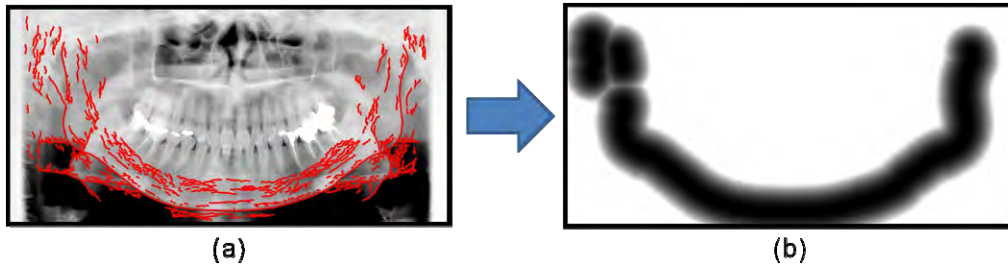


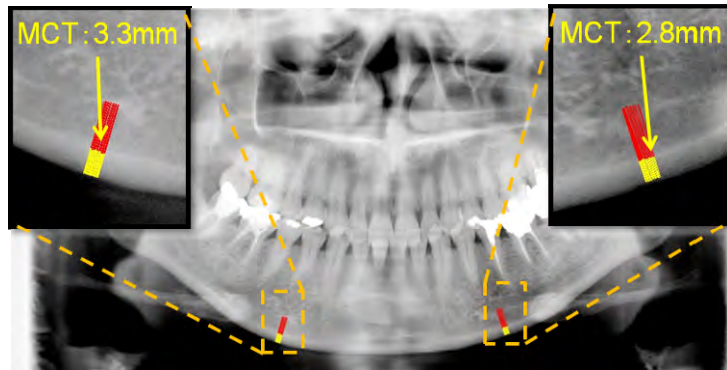
Figure 1 Overview of our proposed method for measuring MCT.



**Figure 2** Mask image specifying 7 regions is created from the training data of mandibular contour.



**Figure 3** Edge component of the image in Step 1. (a) is transformed into the image of Euclidean distance (b).



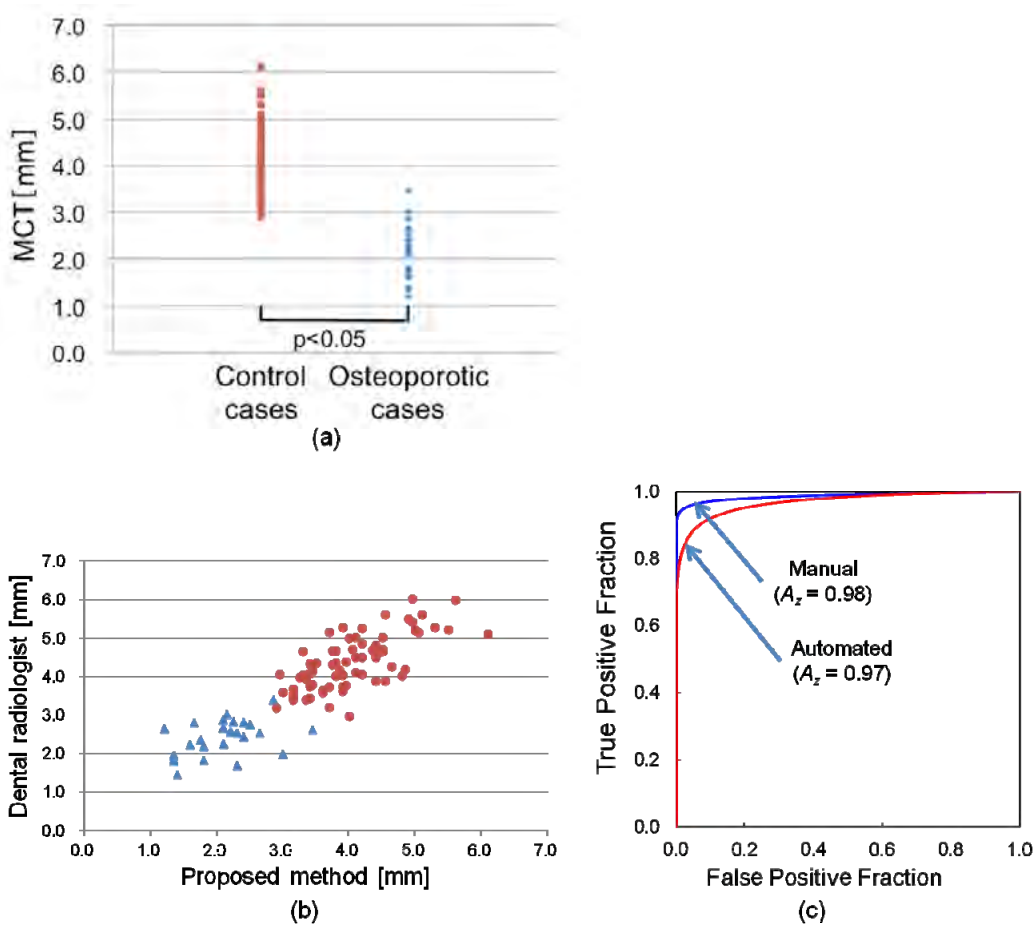
**Figure 4** Example of the MCT measurement results.

### 3. RESULT

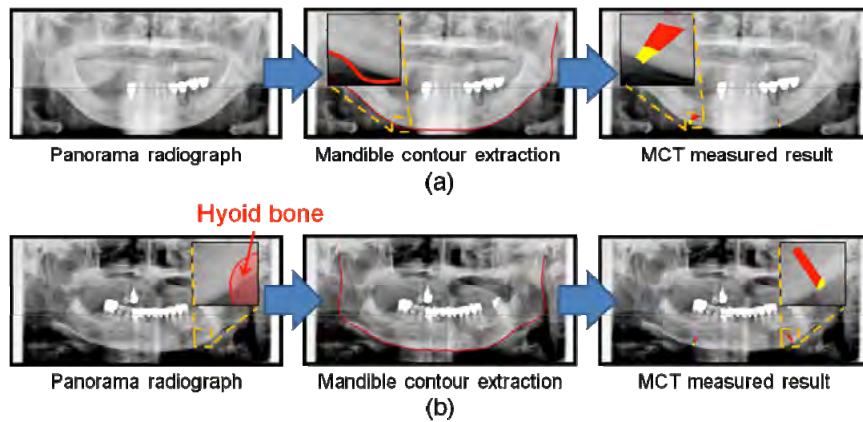
#### 3.1 Evaluation by using our test data

A hundred DPRs (73 control and 27 osteoporotic cases) were used to evaluate our proposed scheme. Detection of the mandibular contour was successful in all cases, so that it was possible to measure MCTs. The average value of MCTs of the control cases was 3.4 mm (standard deviation = 0.56 mm) and that of the osteoporotic cases was 2.1 mm (standard deviation = 0.69 mm). There was a statistically significant difference in MCTs between the control and osteoporotic individuals based on the student's t-test (Fig. 5 (a)). When the threshold length  $\alpha = 2.8$  mm was employed, the sensitivity and the specificity were 92.6 % (25/27 cases) and 100 % (73/73 cases), respectively. In addition, the correlation coefficient between the gold standard by a dental radiologist and result of our proposed scheme was 0.87 (Fig. 5 (b)). Areas under the ROC curves ( $A_2$ ) for our proposed scheme and manual measurement by a dentist were 0.97 and 0.98, respectively (Fig. 5 (c)). There was no significant difference in  $A_2$  between the two schemes. Our proposed method was to measure MCTs in all cases. However, in some cases the MCT measurement results was not accurate. Example images that our method failed to measure MCTs are shown in Fig. 6. There are two causes of the failure in the MCT measurements. One was due to the suboptimal detection of mandibular contour (Fig. 6 (a)), and the other was

due to an obstacle shadow effect of the hyoid bone (Fig. 6 (b)). Therefore, a new process to solve these problems is required in the future.



**Figure 5** Experimental results of measuring the MCTs. (a) Distributions of the MCTs, (b) comparison of the MCT measurements between a dental radiologist and our proposed method, and (c) ROC curves for the manual measurements by the dental radiologist and automated method by a computer.  $A_z$ : Area under the ROC curve.



**Figure 6** Example cases that MCT measurements were failed. (a) Suboptimal mandibular contour detection, (b) Obstacle shadow effect of the hyoid bone.

### 3.2 Preliminary clinical trials by using the stand-alone CAD system

We conducted multiclinic trials by collaboration with Gifu Prefecture Dental Association (Fig. 7). So far, 223 cases obtained in about a month have been processed. Four cases were assessed as suspected osteoporosis by a dental radiologist. The summary of the datasets that were processed in clinical trials is shown in Table 1. When threshold length  $\alpha = 2.8$  mm was employed, the sensitivity was 100 % (4/4 cases), and the specificity was 81.3 % (178/219 cases). An example of suspected osteoporotic case is shown in Fig. 8. The positive predictive value and the negative predictive value were 19.0 % (4/21 cases) and 100 % (178/178 cases), respectively, which were determined after excluding the cases in which the MCTs could not be measured.

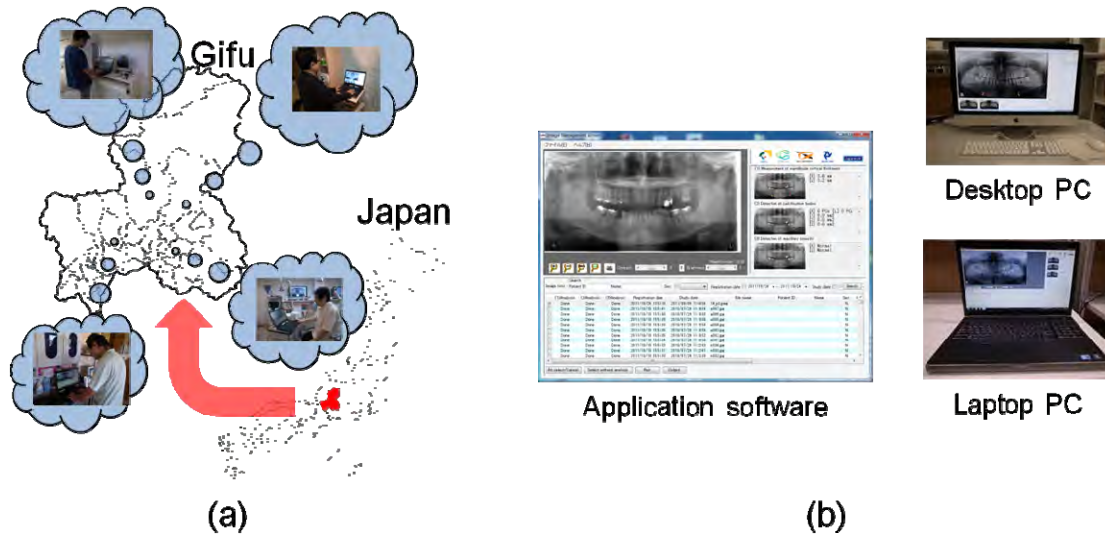
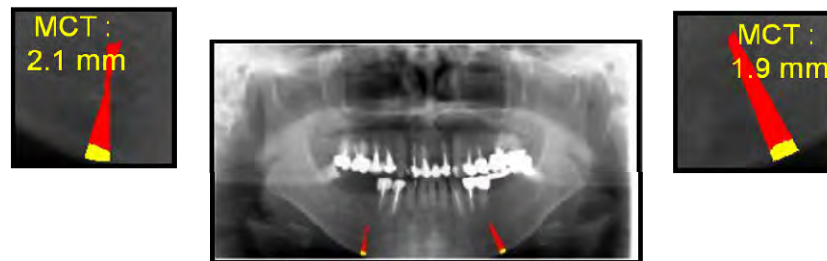


Figure 7 Multi-clinic trials (a) by collaboration with Gifu Prefecture Dental Association by use of stand-alone CAD system (b).

Table 1 The summary of datasets that were processed in clinical trials. SD: Standard Deviation

Institution	A	B	C	D	E
Number of cases	43	19	45	44	72
Suspected osteoporosis	1	0	0	0	3
Average age (SD)	44 (14.7)	39.3 (13.2)	37.7 (15.2)	46.7 (13.2)	60.4 (14.6)
Example image					



Woman, 76 years old

Figure 8 A suspected osteoporotic case.



## 4. CONCLUSION

A computerized scheme that measures the MCTs was developed. Experimental results showed that the sensitivity and specificity for identifying osteoporotic patients were 92.6% and 100%, respectively. The result of clinical trials indicates that our proposed scheme may have a potential to identify osteoporotic patients at an early stage.

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## REFERENCES

- [1] A.Taguchi, "Triage screening for osteoporosis in dental clinics using panorama radiographs," *Oral Diseases*, 16: 316-327, (2010).
- [2] K.Iwai, K.Nisizawa, T.Maruyama, et al., "Nationwide survey of dental radiographic examination and estimation of collective effective dose in Japan, 1999," *Dental Radiology*, 45: 132-142, in Japanese, (2005).
- [3] T.Hayashi, T.Matsumoto, T.Sawagashira, et al., "Computer-assisted detection/diagnosis systems for screening systemic illnesses on dental panoramic radiographs: New collaboration pathway through radiologists, dentists, and computers," 96th Scientific Assembly and Annual Meeting of Radiological Society of North America 2010 (RSNA 2010), Education Exhibits, LL-INE1187-SUA, (2010).
- [4] T.Hayashi, T.Matsumoto, T.Hara, et al., "Computerized identification of osteoporotic patients on panoramic radiographs: The challenge of developing a supplemental screening pathway for detecting asymptomatic patients," 97th Scientific Assembly and Annual Meeting of Radiological Society of North America 2011 (RSNA 2011), Scientific Formal (Paper) Presentations, SSA19-07, (2011).
- [5] H.Fujita, T.Hayashi, T.Sawagashira, et al., "Effect of screening for systemic diseases using panoramic radiographs: The new role of preventive care in dentistry," 97th Scientific Assembly and Annual Meeting of Radiological Society of North America (RSNA 2011), Education Exhibits, LL-INE1185-WEA, (2011).
- [6] H.Fujita, T.Hara, A.Katsumata, et al., "Computer-aided detection system and schemes using panoramic radiographs," Patent pending in Japan, 2011-060256, (applied on 18 Mar, 2011).