A new screening pathway for identifying asymptomatic patients using dental panoramic radiographs

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ABSTRACT

To identify asymptomatic patients is the challenging task and the essential first step in diagnosis. Findings of dental panoramic radiographs include not only dental conditions but also radiographic signs that are suggestive of possible systemic diseases such as osteoporosis, arteriosclerosis, and maxillary sinusitis. Detection of such signs on panoramic radiographs has a potential to provide supplemental benefits for patients. However, it is not easy for general dental practitioners to pay careful attention to such signs. We addressed the development of a computer-aided detection (CAD) system that detects radiographic signs of pathology on panoramic images, and the design of the framework of new screening pathway by cooperation of dentists and our CAD system. The performance evaluation of our CAD system showed the sensitivity and specificity in the identification of osteoporotic patients were 92.6 % and 100 %, respectively, and those of the maxillary sinus abnormality were 89.6 % and 73.6 %, respectively. The detection rate of carotid artery calcifications that suggests the need for further medical evaluation was approximately 93.6 % with 4.4 false-positives per image. To validate the utility of the new screening pathway, preliminary clinical trials by using our CAD system were conducted. To date, 223 panoramic images were processed and 4 asymptomatic patients with suspected osteoporosis, 7 asymptomatic patients with suspected calcifications, and 40 asymptomatic patients with suspected maxillary sinusitis were detected in our initial trial. It was suggested that our new screening pathway could be useful to identify asymptomatic patients with systemic diseases.

Keywords: Dental panoramic radiography, Computer-aided detection system, Osteoporosis, Carotid artery calcifications, Maxillary sinusitis, New screening pathway

1. INTRODUCTION

Findings of panoramic radiography that plays a very important role in clinical dentistry include clinical information on not only dental conditions but also radiographic signs that are especially suggestive of possible systemic diseases. For example, decrease in the mandibular cortical thickness is one of radiographic signs of osteoporosis [1]. Calcifications within the carotid artery that indicate the need for further medical evaluation, can be observed on panoramic radiography [2]. Radiopacity of maxillary sinus is one of the abnormality signs such as maxillary sinusitis [3]. Supplemental screening of systemic diseases on routinely-used panoramic images in dentistry has a potential to detect asymptomatic patients. However, it is not easy for general dental practitioners to pay careful attention to such signs. The aim of this study was to develop a computer-aided detection (CAD) system that detects radiographic signs associated with systemic diseases on panoramic images and to present a new screening pathway by cooperation of dentists and the CAD system.

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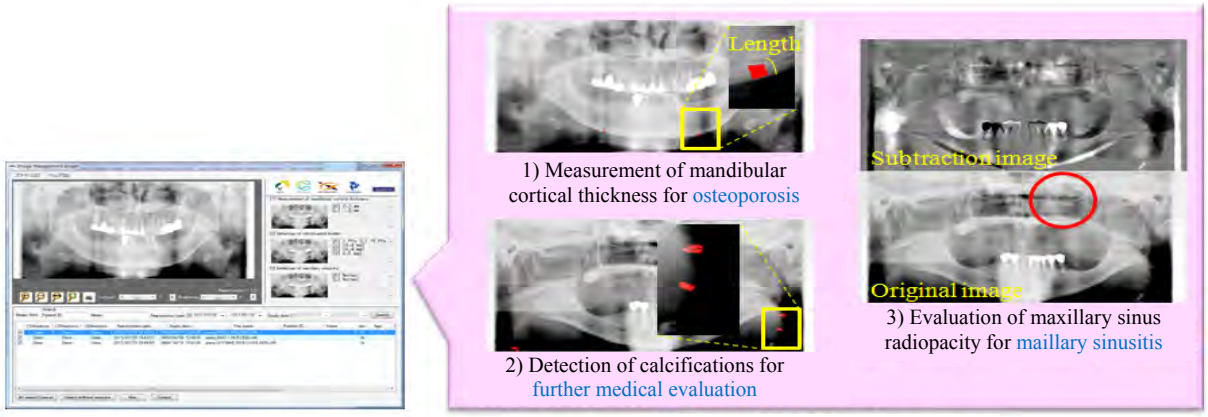


Fig.1 Overview of our CAD system.

2. CAD SYSTEM FOR DETECTING RADIOGRAPHIC SIGNS

The overview of our CAD system is illustrated in Fig.1. Computerized schemes for detecting three radiographic signs related to osteoporosis, arteriosclerosis, and maxillary sinusitis were implemented in the CAD system [4-9]. The process flow of each CAD scheme is briefly described below.

2.1 Measurement of mandibular cortical thickness

Mandibular contour, which is a fundamental anatomic structure on panoramic radiography, is useful to design a computerized scheme. Canny edge detector, similar image search technique, and active contour method are used to extract the mandibular contour [8]. And then, positions of mental foramina are estimated based on the result from the image search technique. After that, straight lines perpendicular to the mandibular contour which pass through the mental foramina are determined. Finally, thickness of the mandibular cortex is decided by the analysis of the grayscale profile on the straight lines.

2.2 Detection of carotid artery calcifications

Carotid artery calcifications are visualized below and lateral to the mandible on panoramic radiographs. That's why regions of interest (ROI) for calcifications are set based on the mandibular contour. And then, grayscale top-hat filter that corrects for trends in background values is used to detect initial candidates for calcifications. However, some parts of cervical vertebrae and hyoid bone that are included in the ROI are also detected as the initial candidates. Rule-based method and support vector machine based on the features of the candidates are applied to remove such false positives (FPs).

2.3 Evaluation of maxillary sinus radiopacity

Contralateral subtraction technique is used to detect the radiopacity in both sinuses. This technique consists of the following three steps; 1) image filtering of the smoothing and Sobel operation for noise reduction and edge extraction, respectively, 2) image registration of flip horizontal image by using mutual information, and 3) image display method of subtracted pixel data.

2.4 Development of stand-alone CAD system

Application software called “Dental Viewer” is developed. It has simple functions that consist of image display, database, and CAD results. Image management screen in Fig.1 shows one of screen captures of the Dental Viewer. First, one need to register the image file to the database of the Dental Viewer. The Dental Viewer supports a drag-and-drop to register the image file. And then, select the target image from the database, and press analysis button. Soon after, three CAD schemes will be executed sequentially. Its processing cost is about one minute. When the process is completed, dental practitioner can see the intermediate processes and results of the CAD. Dental Viewer is available on any personal computer.

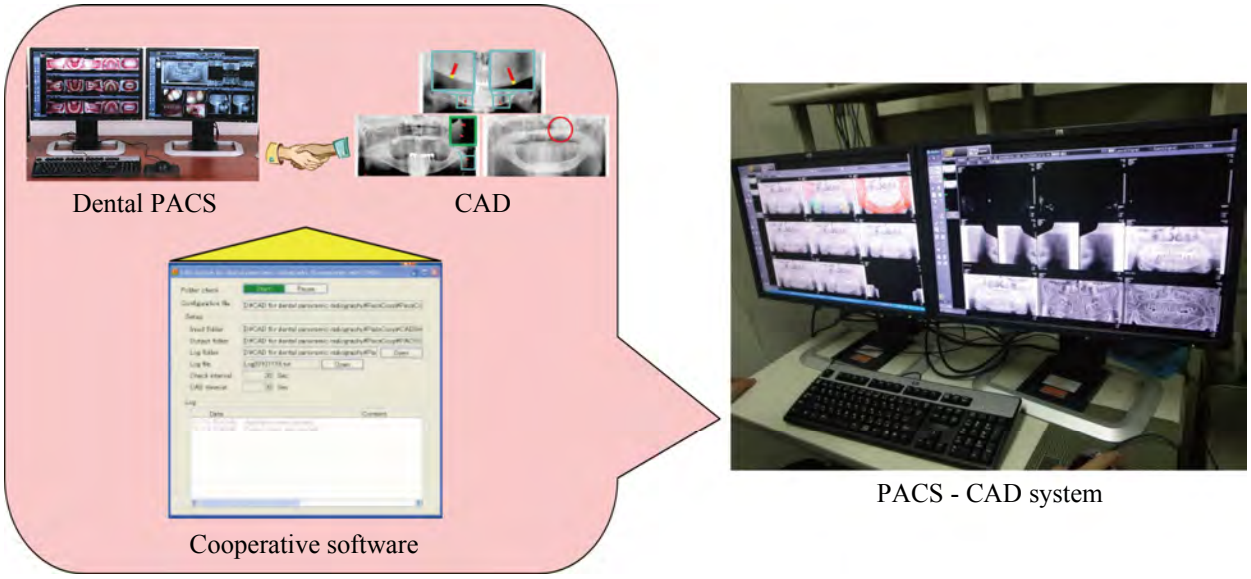


Fig.2 Illustration of PACS - CAD system.

2.5 Development of PACS - CAD system

Dental picture archiving and communication system (PACS) was developed in recent years, and it has been started to use in dental clinics. Implementation of CAD functions on dental PACS (PACS - CAD system) is expected to improve the usability of the system. For example, (i) do not have to input images to the CAD system; (ii) CAD results can be used on the PACS viewer in which dentists are familiar with the operation. Cooperative software we developed can make our CAD functions available on the dental PACS (see Fig.2).

3. NEW SCREENING PATHWAY VIA DENTAL CLINICS WITH CAD

Taguchi presented a new idea of "preliminary diagnosis of systemic diseases in the dental clinic" [1]. Its attempt has a potential to accelerate the early detection of systemic diseases. To facilitate its new role of dental practitioners, we present a new screening pathway by cooperation of the dentists and the CAD system as shown in Fig.3. Overview of the new screening pathway is as follows. In the routine work, panoramic radiographs are used to examine dental diseases in dental clinics. At this time, dentists send the images to CAD system as an extra task. Once upon receiving the images, our CAD system automatically runs the image analysis and the resulted images and reports are sent to dentists. If pathologic signs are detected, CAD alerts dentists. And then, refer to the CAD results, supplemental screenings of systemic diseases are performed by dentists. Finally, dentists inform patients of the risk for systemic diseases. If the patients desire, the dentists will refer to the medical clinics.

4. RESULTS

4.1 Performance evaluation of our CAD schemes using laboratory dataset

The following database carefully checked by the dental radiologists was used to evaluate the performance of our CAD system: 100 images including 27 thin mandibular cortex cases were employed to measure mandibular cortical thickness, 34 images including carotid artery calcifications were used for detection of calcifications, and 56 images including 32 abnormal cases were used to evaluate the maxillary sinus radiopacity. All these images were originally imaged for routine clinical dentistry.

Sensitivity and specificity in the detection of thin mandibular cortex were 92.6 % and 100 %, respectively, when threshold length was set to 2.8 mm [5]. The detection rate (sensitivity) of the calcifications was 93.6 % with 4.4 FPs per image [6]. Sensitivity and specificity in the detection of the maxillary sinus abnormality were 89.6 % and 73.6 %, respectively, when 3 dental radiologists used subtraction image [7].

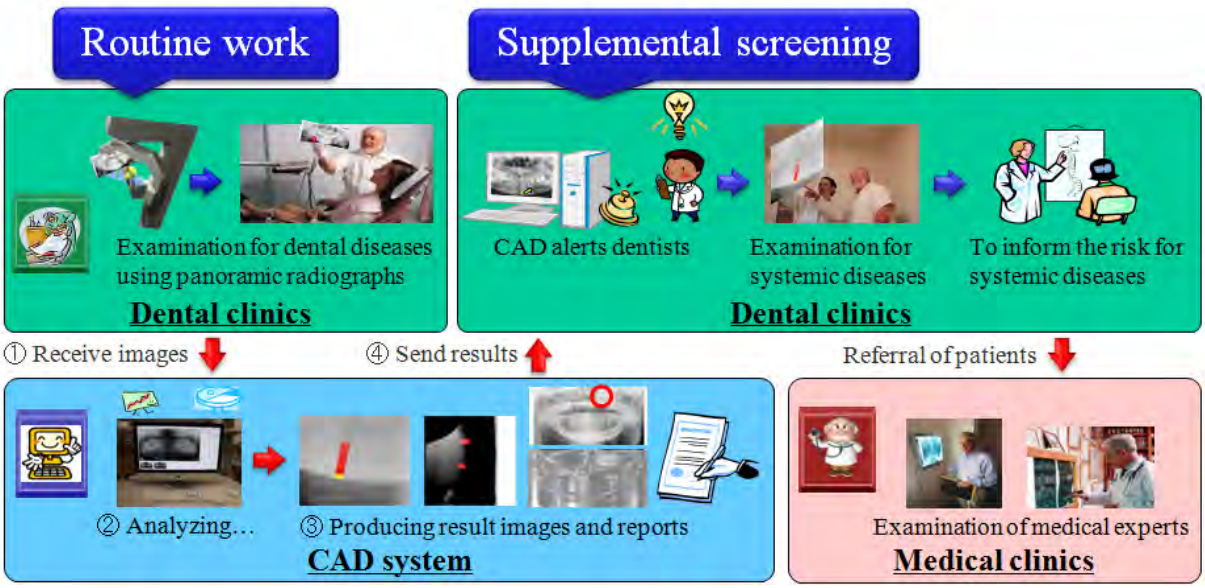


Fig.3 New screening pathway via dental clinics with CAD system.

(a) (b) (c) (d)

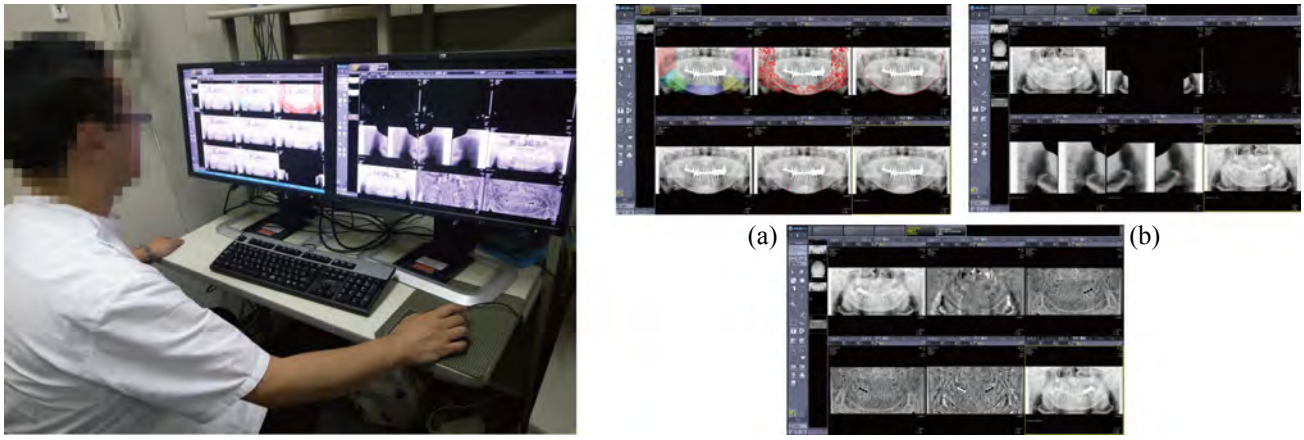
Fig.4 Preliminary clinical trials of the new screening pathway in dental clinics. (a): The orientation on the preliminary clinical trials. (b-d): Examples of the use of the stand-alone CAD system by general dental practitioners.

4.2 Preliminary clinical trials by using the stand-alone CAD system

To validate the utility of the new screening pathway, preliminary clinical trials that cooperated with Gifu Prefecture Dental Association were conducted. The orientation on the concept of our new screening pathway along with the explanation on the method for operating our CAD system was held in advance of the trials (see Fig. 4). Five dental practitioners participated in the orientation. Laptop computers that installed our CAD software were lent to the dental practitioners. Panoramic radiographs, which scanned for the examination of dental conditions, were applied to our CAD system at each dental clinic. 223 panoramic images were processed by our CAD system. Sensitivity and specificity in the detection of thin mandibular cortex were 100 % (4 / 4) and 81.3 % (178 / 219), respectively, when threshold length was set to 2.8 mm. The detection rate (sensitivity) of the calcifications was 53.8 % (7 / 13) with 1.2 FPs per image. The detection rate (sensitivity) of the radiopacity in bilateral maxillary sinuses was 72.7 % (40 / 55) with 0.3 FPs per image. Note that the detections by the dental radiologists were defined as the ground truth in this trial.

4.3 Preliminary trial by using the PACS - CAD system

The preliminary trial to demonstrate the clinical usefulness by use of the PACS-CAD system was conducted. 100 cases selected at random were processed, and the following suspected cases were detected by dental radiologists that checked the result images on the PACS-CAD system: (i) 3 cases with suspected osteoporosis; (ii) 2 cases with suspected carotid artery calcifications; and (iii) 4 cases with suspected maxillary sinusitis. Fig.5 shows an example of the result image that the dental radiologists checked. The seamless integration of image viewing, CAD analysis and reporting in a



PACS - CAD system

Fig.5 Preliminary trial by using the PACS - CAD system. (a) The result images for measuring cortical thickness. (b) The result images for detecting calcifications. (c) The result images for evaluating maxillary sinus radiopacity.

computer were achieved. Dental radiologists estimated that the PACS - CAD system may be useful in interpreting panoramic images.

5. DISCUSSIONS

Dental panoramic radiography has a new potential to be used as a supplemental screening tool for early detection of systemic diseases such as osteoporosis and arteriosclerosis. CAD is expected as the technology of assisting such attempt. So far, some CAD schemes for systemic diseases on panoramic radiography have been presented. For the detection of osteoporosis by use of panoramic radiography, the following schemes have been shown: Taguchi et al [10] have developed a diagnosis support device based on the evaluation of the morphology of the mandibular cortex; Asano et al [11] have developed a diagnosis support device based on the measurement of the mandibular cortical thickness; Kavitha et al [12] proposed a new approach on the basis of continuous measurements; Devlin et al [13] presented an automated method for risk assessment of osteoporosis; Allen et al [14] proposed a computerized scheme by use of active shape models; and Roberts et al [15] proposed a computerized scheme by use of active appearance models. Also, Shinjo et al [16] and Izumi et al [17] proposed computerized schemes for the detection of calcifications by use of panoramic radiography. To the best of our knowledge, multi-institutional clinical trials by use of CAD on panoramic radiography have not been conducted by any other groups.

10 million panoramic images are obtained per year in Japan. That's why the preliminary examination by dental practitioners has a potential to accelerate early detection of systemic diseases. This study conducted the preliminary clinical trials by use of our stand-alone CAD system. To date, 4 asymptomatic patients with suspected osteoporosis, 7 asymptomatic patients with suspected calcifications, and 40 asymptomatic patients with suspected maxillary sinusitis were detected in our initial trial. It was suggested that our new screening pathway was useful to identify asymptomatic patients with systemic diseases. It was also suggested that the preliminary trial by use of the PACS-CAD system was helpful in detecting systemic diseases by the dentists.

However, approximately 50% of cases in clinical trials could not be processed by our CAD. The main cause was the variation in the image quality of panoramic radiographs. Digital panoramic scanners are rapidly spreading in dental clinics. As it stands now, there are large variations in the image quality of panoramic images. Dental X-ray head phantom made by Kyoto Kagaku (Kyoto, Japan) was used to show the effect of the inter-scanner variation on panoramic images. Fig. 6 shows some image examples of the large variations in image quality. It should be noted that such variations lead to poor performance of the CAD system.

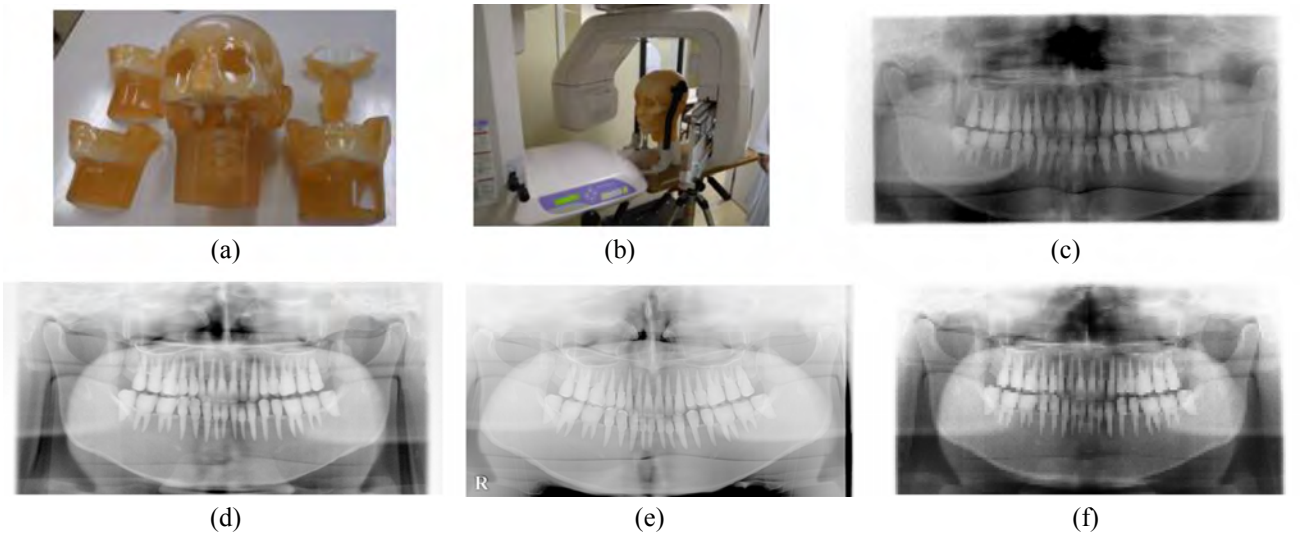


Fig.6 Effect of the inter-scanner variation on panoramic images by use of the dental X-ray head phantom. (a) Dental X-ray head phantom. (b) One example of scanning of the phantom. (c-f) Four examples of panoramic images in different institutions (scanners).

6. CONCLUSION

A CAD system that measures the mandibular cortical thickness, detects carotid artery calcifications, and evaluates the maxillary sinus radiopacity was developed. Our initial trials revealed that our new screening pathway could identify asymptomatic patients with osteoporosis, carotid artery calcifications, and maxillary sinusitis. Development of the algorithm that reduces the image-quality variation in panoramic images is needed to improve the performance of our CAD system.

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REFERENCES

[1] A Taguchi, "Triage screening for osteoporosis in dental clinics using panoramic radiographs," *Oral Dis*, 16: 316-27 (2010).

[2] E Ertas, Y Sisman, "Detection of incidental carotid artery calcifications during dental examinations: Panoramic radiography as an important aid in dentistry," *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 112: e11-7 (2011).

[3] E Imaizumi, "Clinical study on the detection of maxillary sinus disease by means of panoramic and waters' projections," *Kyushu-shika-gakkai-zasshi*, 44: 597-614 (1990).

[4] 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 2011 (RSNA 2011), Education Exhibits*, LL-INE1185-WEA (2011).

[5] T Matsumoto, T Hayashi, T Hara, et al, "Automated scheme for measuring mandibular cortical thickness on dental panoramic radiographs for osteoporosis screening," *Proc of SPIE Medical Imaging 2012: Computer-Aided Diagnosis,* 8315, in press (2012).
[6] T Sawagashira, T Hayashi, T Hara, et al, "An automatic detection method for carotid artery calcifications using top-hat filter on dental panoramic radiographs," *Proc of the 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, 6208-6211 (2011).
[7] T Hara, S Mori, T Kaneda, et al, "Automated contralateral subtraction of dental panoramic radiographs for detecting abnormalities in paranasal sinus," *Proc of SPIE Medical Imaging 2011: Computer-Aided Diagnosis*, 7963: 79632R (2011).
[8] 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).
[9] H Fujita, T Hara, A Katsumata, et al, "Computer-aided detection system and schemes using panoramic radiographs," *Patent pending in Japan*, 2011-280656 (applied on 22 Dec, 2012).
[10] A Taguchi, T Nakamoto, A Asano, "Osteoporosis diagnosis support device using panorama X-ray image," *US Patent*, 2006/0239532 A1 (filed 24 Aug, 2006).
[11] A Asano, A Taguchi, T Nakamoto, et al, "Osteoporosis diagnosis support device," *US Patent*, 7,916,921 B2, 29 Mar (2011).
[12] MS Kavitha, F Sampoa, A Asano, et al, "Computer-aided measurement of mandibular cortical width on dental panoramic radiographs for identifying osteoporosis," *J Invest Clin dent*, 3: 36-44 (2012).
[13] H Devlin, PD Allen, J Graham, et al, "Automated osteoporosis risk assessment by dentists: A new pathway to diagnosis," *Bone*, 40: 835-842 (2007).
[14] PD Allen, J Graham, EJ Marjanovic, et al, "Finding indications of osteoporosis in panoramic dental radiographs using active shape models: The OSTEODENT project," *Proc of MIUA 2007*, 91-95 (2007).
[15] MG Roberts, J Graham, H Devlin, et al, "Improving the detection of osteoporosis from dental radiographs using active appearance models," *Proc of IEEE ISBI'10*: 440-3 (2010).
[16] K Shinjo, M Muneyasu, K Fujita, et al, "Improvement of the detection method for carotid artery calcification in dental panoramic radiographs," *Proc of ISPACS 2009*, 119-122 (2009).
[17] Y Izumi, K Shinjo, M Muneyasu, et al, "An automatic detection method for carotid artery calcification in dental panoramic radiographs for screening of atherosclerosis," *IEICE-MI2010-58*, 110: 43-48 (2010).