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Dental panoramic image analysis for enhancement biomarker of mandibular condyle for osteoporosis early detection

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Abstract. Osteoporosis is a degenerative disease characterized by low Bone Mineral Density (BMD). Currently, a BMD level is determined by Dual Energy X-ray Absorptiometry (DXA) at the lumbar vertebrae and femur. Previous studies reported that dental panoramic radiography image has potential information for early osteoporosis detection. This work reported alternative scheme, that consists of the determination of the Region of Interest (ROI) the condyle mandibular in the image as biomarker and feature extraction from ROI and classification of bone conditions. The minimum value of intensity in the cavity area is used to compensate an offset on the ROI. For feature extraction, the fraction of intensity values in the ROI that represent high bone density and the ROI total area is perfored. The classification will be evaluated from the ability of each feature and its combinations for the BMD detection in 2 classes (normal and abnormal), with the artificial neural network method. The evaluation system used 105 panoramic image data from menopause women which consist of 36 training data and 69 test data that were divided into 2 classes. The 2 classes of classification obtained 88.0% accuracy rate and 88.0% sensitivity rate.

1. Introduction

Degenerative bone disease which is indicated by the occurrence of low bone mineral density (BMD) may occur in older people. This disease can increase the fragility, fractures risk and lowering mechanical force on supporting body normal activity^[1]. Actually, osteoporosis can develop in both men and women, but women postmenopausal have more significant risk. The decrease of bone mineral density in postmenopausal woman is a direct result from the loss of estrogen. Osteoporosis is also known as a silent disease because people may not know that they have osteoporosis until their bones become so weak that a sudden strain, bump, or fall causes a hip to fracture or a vertebra to collapse.

The gold standar of measurement bone mass, bone mineral density or other aspect related to bone structure is dual energy X-ray absorptiometry (DXA). In the developing countries, the number of DXA apparatus is relatively limited, therefore early osteoporosis detection using DXA becomes not easy to perform [1, 2].

Usually older people may have greater opportunity to visit dentists for dental treatment than visit medical expert to measure bone density using DXA. Previous researcher states that there is a correlation

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between condition of hip and mandibular bone [1]. Therefore, information of mandibular bone that is recorded using panoramic radiography is becoming alternative to be researched as early detection of osteoporosis [3-5]. Various studies have been proposed to measure the width of mandibular cortical bone or pattern of trabecular bone that is imaged on panoramic image as osteoporosis prediction. In patients with postmenopausal osteoporosis, trabecular number decreased due to reduced estrogen hormones that regulate the transport of calcium into bone [2, 4, 5]. The architecture of trabecular bone changes due to osteoporosis could be imaged in panoramic radiography images. However, a spesific processing scheme must be development to extract the pattern of trabecular bone image in the spesific region.

This work reported alternative scheme, that consists of the determination of the Region of Interest (ROI) in the image as a biomarker and feature extraction from ROI and classification of bone conditions. ROI was taken on the left and right condyle mandibular. The classification will be evaluated from the ability of feature and its combinations for the BMD detection in 2 classes (normal and abnormal) with the artificial neural network method.

2. Material and methods

2.1. Material

The database of panoramic images for supporting this research was prepared by Department of Dentomaxilofacial Radiology, Faculty of Dentistry, Padjadjaran University. Each patient data consist of panoramic image and BMD information that was determined from DXA. The data were acquired from 50-85 year old postmenopausal women. Two panoramic radiograph machines were used, i.e. orthopantomograph E-Woo EPX-Impla at 8 mA and the voltage of 66 kV and panoramic radiograph Rotograph Evo at 13,8 mA and the voltage of 74 kV. The total samples were 105 patients of postmenopousal women.

2.2. Methods

The mandibula bone of patient was imaged using extra-oral imaging where the arrangement of the teeth was projected on the panoramic image plane. In this study, the Region of Interest (ROI) was taken on the dental panoramic radiograph image that shows the area of the jaw bone. Figure-1A illustrates the process of panoramic imaging. The film or digital detector and also X-ray source will be rotated in several steps, until covering the whole mandibula bone. The results of the process is panaromic images (figure 1b).



Figure 1. (a). Illustration process of panarmic imaging. (b). Panaromic image and ROI region on the condyle marked with "red arrow".

For the extraction of digital biomarker, ROI was taken on the left and right *condyle mandibular* (lower jaw bone ends). Due to the condyle shape, the specific method is used to define the ROI with follow the shape of the condyle bone. The ROI region is marked with "red arrow" in the Figure 1B. Condyle mandibular is selected as the ROI for biomaker because its region is less affected by local factor such as infection.

Ideally, the image intensity value on the ROI (I_{ROI}) is only proportional to the attenuation factor, only on the condyle area (μ_B). However, a superimpose problem occurs in the panaromic imaging. Due to this problem, the intensity on the condyle area is modelled as:

$$I_{ROI} = I_S \exp(\mu_A + \mu_B + \mu_C) x \tag{1}$$

where I_s is intensity of source, μ_A attenuation factor of soft-tissue and μ_C is attenuation factor of air cavity and x is thicknes of tissue. The factor of μ_A and μ_C are assumed as background offset intensity on the I_{ROI} . To minimize the problem of background offsets, it was determined that the minimum of variance value in the cavity is that had the minimum attenuation X-ray in the surrounding condyle area. If the background offset is represented by I_{offset} , then the compensated I_{ROI-C} is modelled as:



Figure 2. Proposed scheme of image analysis for osteoporosis early detection.

The steps of compensation process are shown in Figure 2. The feature extraction is processed on I_{ROI-C} , in order to obtain quantification value of bone condition prediction or digital biomarker. We assume that, on I_{ROI-C} , the gray-value is proportional with a bone density on the condyle. The pattern of gray scale variation represents the pattern of trabecular bone in condyle. Based on the assumption, segmentation was done on I_{ROI-C} to determine the lowest value of bone density (marked with 0), based on threshold that is chose based on isodata algorithm. Next, if the gray value on I_{ROI-C} is higher than the threshold, the gray value on I_{ROI-C} is marked with 1. After the binary image of I_{ROI-C} is obtained using segmentation process, the final step determines IFEATURE that is formulated as: (2)

$$I_{FEATURE} = I_{ROI-c} \times (\text{biner of } I_{ROI-c})$$
⁽⁵⁾

(1)



Figure 3. Step for determine fraction value.

The gray value of $I_{FEATURE}$ is the representation of digital biomarker of bone density prediction on trabecular bone. The fraction value is determined by the ratio between total sum of gray value in $I_{FEATURE}$ and total sum of gray value in I_{ROI-C} , if assumed that the gray value on I_{ROI-C} has maximum value on the whole ROI.

The fraction values (FRAC) from left and right condyle from each patient data are tabulated with correspond to BMD values (on T-score) that were determined by DXA. For classification, artificial neural network (ANN) with multilayer perceptron (MLP) architecture was used to classify 2 classes of bone conditions (i.e. normal and abnormal).

Patient	Image of right fraction	Image of left fraction	Result of DXA	Right fraction value	Left fraction value
Patient 1			Normal	1. 0,180 2. 0,178 3. 0,178	1. 0,181 2. 0,181 3. 0,178
Patient 2		A State	Osteoporosis	1. 0,018 2. 0,021 3. 0,015	1. 0,049 2. 0,050 3. 0,054
Patient 3			Normal	1. 0,102 2. 0,102 3. 0,098	1. 0,024 2. 0,018 3. 0,018
Patient 4			Osteoporosis	1. 0,051 2. 0,052 3. 0,053	1. 0,075 2. 0,077 3. 0,079

Table 1. The sample results of fraction value from 2 normal and 2 osteoporosis patient data.

3. Results

The sample results of fraction value is tabulated on Table 1. These results are determined from 2 normal and 2 abnormal patient data. For patient with less bone density, the value of abnormal FRAC is less than normal FRAC. However, from 105 patient data, the range of FRAC values are often overlap between normal and abnormal condition. The overlap of FRAC value is usually only on the left or right of condyle. To overcome these problem, the set of FRAC pattern related with T-score value are trained using ANN with 4 layer-MLP. The evaluation system used 105 panoramic image data from menopause women and from different image devices which consist of 36 training data and 69 test data that were divided into 2 classes proportionally.

	2			
Aatual	Prediction			
Actual	Normal	Osteoporosis		
Normal	True Positive	False Negative		
Inormat	(TP)	(FN)		
Ostaanarasis	False Positive	True Negative		
Osteoporosis	(FP)	(TN)		

Table 2. Uncertainty matrix.

Testing of methods and systems that have been designed are performed using accuracy and sensitivity [3]. The accuracy and sensitivity value of classification can be defined using the uncertainty matrix elements as follows:

$$Accuracy(\%) = \frac{TP + TN}{TP + TN + FP + FN} x100$$
(4)

$$Sensitivity(\%) = \frac{TP}{TP + FN} x100$$
(5)

where the TP, TN, FN and FP are tabulated on table 2. The proposed scheme has performance of 88.0% in accuracy rate and 88.0% in sensitivity rate.

4. Conclusion

From the results, it was concluded that the image analysis scheme of dental panoramic radiograph image can be used as a basis of computer aided diagnosis for dentist in providing early information about osteoporosis. Feature extraction of fraction value on the condylus areas are promoted as digital biomarker. The rate of classification based on 69 test data is 88.0% in accuracy rate and 88.0% in sensitivity rate. The representation of the bone mineral density condition has not been able to achieve the results of 100%. It may be caused the quality of dental panoramic image is varied due to size of the patient's head and noise from X-ray detector. To improve the ability of the system, it is needed many test data of the BMD value based on DXA value at the distal radius and femur area.

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