An Association Between Osteoporosis and the Mandibular Cortical Bone Among Post-Menopausal Women as Revealed by Pixel Intensity Imagery in Panoramic Radiograph

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Abstract

The Mandibular cortical bone is used as a recommended index for detecting bone mineral density (BMD) loss. This study aimed to determine the impact of the BMD reductions among postmenopausal women, by measuring the pixel intensity (PI) values in the mandibular cortical bones that were identified on digital panoramic radiographs.

The PI values were obtained from a cross-sectional sampling approach of the 65 postmenopausal women used in the study. One of the baseline diagnoses of osteoporosis is the Tscore measurement taken from each subject's femora. The mandibular cortex index (MCI) classification of individual dental panoramic radiographs followed the criteria described by Klemetti et al. Imaging software was used to calculate the average PI values in the mandibular bilateral cortical bones. The Kruskal-Wallis H with Tukey post hoc tests, were used to assess the PI value differences between the categorized MCI groups.

The mean PI of the BMD reduction group was less than that of the normal BMD one, and a pronounced correlation was seen between the PI values and the categorized MCI.

Within the limitations of this study, a negative correlation was found between the mandibular cortical bone's PI values and the BMD reductions. The PI values were related to the MCI classifications which were calculated from the digital panoramic radiographs.

Clinical article (J Int Dent Med Res 2023; 16(4): 1647-1651) Keywords: Pixel intensity, mandibular cortical bone, osteoporosis, panoramic radiograph, postmenopausal women.

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Introduction

When an elderly person suffers from a fracture, they are examined to determine if they have osteoporosis. Osteoporotic fractures cause a low quality of life, some functional impairment, and increased mortality. The most widely used diagnostic technique is based on a dual energy x-ray absorptiometry (DXA).¹ The World Health Organization bases osteoporosis diagnosis of postmenopausal women, on the T-scores of the bone mineral density (BMD) measurements. Its guidelines categorize the BMD values into three

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Associated Professor Dr. Weeraya Tantanapornkul DDS, PhD Department of Oral Diagnosis, Faculty of Dentistry, Naresuan University, Phitsanulok 65000, Thailand. E-mail: <u>weerayat@nu.ac.th</u> groups, which are normal (T-score \geq -1.0), osteopenia (-1.0 \leq T-score \leq -2.5), and osteoporosis (T-score \leq -2.5).²

When women reach the menopause stage in life, there is an increase in bone loss and osteoporotic risk. Referring all postmenopausal women for BMD testing is rather problematic, due to the cost and the limited number of facilities available.³ Many organizations such as the WHO, developed questionnaires as a simple tool to identify women with a low BMD.4-6 However, their quality variations have led to different treatment recommendations because of their suitability for specific populations.⁷ A panoramic radiograph would be able to show changes in the characteristics of the jaw bone, which could be advantageous in identifying osteoporosis. There are many documented osteoporosis-screening methods used in radiography such as, mandibular cortex, mental,

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antegonial, and panoramic mandibular indices.⁸⁻

An appearance of the mandibular cortex (MCI) in the radiograph is highly recommended for the screening procedure, because of a qualitative association between the hip and spinal indices.¹²⁻¹⁵

The BMD loss is identified by using the most cited radiomorphometric MCI, despite its limitations from both intra- and inter-observer agreements.¹⁶ Some practical methods include the training of the health professionals to accurately diagnose radiographs, to minimize the disagreements in judgments.¹⁷ An automatic procedure was invented to efficiently and reliably process the panoramic radiographs, enabling the early detection of osteoporosis.¹⁸ Despite its usefulness, the artificial intelligence requires some specific combinations, which includes the integration of several image segmentation methods to achieve the proposed goal.¹⁹

Based on the assessment of the x-ray attenuation coefficient of the mineral material in the bony tissue, such as histogram and computed tomographic (CT) values, some nondestructive screening tools for osteoporosis have been applied to overcome the MCI's limitations.^{20,} ²¹ In a 2-dimensional (2D) digital radiograph that contains pixel intensity (PI), the gray scale color information within the individual pixels. corresponds with the absorbed x-ray intensity at that location. The CT values are obtained from an image histogram of the PI values' distribution in the radiograph, and the gray shades are calculated from various tissues in a 3dimensional CT scan. The gray values from a CT machine strongly correlate with the density of the materials, despite the artifacts' influences on the values.²² An assessment of the PI values in the 2D dental image during a standard visit to the dentist, is an effective technique to acquire the BMD with limited influences of the artifacts.

Researchers have endeavored to overcome the limitations of using the PI values for the detection of osteoporosis. However, a low BMD that is diagnosed using the image PI is controversial due to the exposure conditions, patient's posture, image file formats, and software measurements.²² We hypothesized, that the low BMD could be revealed by the reduction of the PI values in the mandibular cortex area. The MCI's limitations and the advantages of the PI information were taken together. Hence, this

study aimed to investigate the PI of the cortical bone, and the MCI in menopausal women of different ages and their amenorrhoeic periods, by minimizing the aforementioned effects.

Materials and methods

The ethical committee of our university approved this cross-sectional research to ensure the protection of patients before the study began (IRB Number 0645/60). The informed consent was obtained from all patients.

Thirty digital panoramic radiographs were taken using an X-ray machine (Veraview X800; Morita, Kyoto, Japan), which included using 10 mA and a kV that ranged from 60 to 100, to calibrate our methods for the detection of osteoporosis.

Three oral radiologists attended the session that included the calibration technique to view, evaluate, group, and select the region of interest (ROI) in the radiographs.

All the female subjects were aged over 55 and had amenorrhoeic. They also had their Tscore BMD, no mandibular pathology, and no history of any medications that had affected the metabolism of their bones. Therefore, they were required to have a digital panoramic radiography of their jaws.

The MCI was evaluated from the cortical bone which is located distally to the mental foramen, and was visualized on the left side of the images. Digital Imaging and Communications in Medicine was used to store all anonymous panoramic images. All the patients' personal information, medical history, and BMD results were treated as strictly confidential to all observers at the time of the radiographic evaluations.

The observers evaluated the MCI under regular office ambient lighting by using these three classifications²³, (1) normal cortex (bilateral even and sharp endosteal cortical margins), (2) mild-to-moderate cortex erosion (bilateral one or three endosteal cortical residues), and (3) severe cortex erosion (heavy endosteal cortical residues and porous cortex) designated as C1, C2, and C3, respectively. Each observer completed the task in isolation, and all the results were kept secret. The observers then repeated the test seven days later under the same conditions.

In each digital panoramic radiograph, the observers determined a 1-cm2 ROI below the

mental foramen, which commenced at the periosteal margin of the mandibular cortex to the surface of the endosteum (Figure 1). The measurement function software (Uniweb Viewer; EBM Technologies Incorporated, Taipei, Taiwan) automatically calculated the average PI value of the selected ROI.



Figure 1. A digital panoramic radiograph of an elderly woman's maxillary and mandibular teeth and bony structure, shows a 1-cm² region of interest (black box) and the mental foramen (black oval) in her left mandibular cortex. L, left; R, right.

Statistical analyses

An analysis of the DXA scan sequences of the left femur using the T-score values which indicated osteoporosis², while the Chi-square test of independence, determined an association between the MCI and the hip T-score, respectively. The measurements of the PI values were conducted, and then a kappa analysis was used to calculate the intra- and inter- agreements by the observers. The Spearman correlation (ρ) was used to specify the relationship of the mandibular cortex PI values of the subjects' ages, and their amenorrhoeic history period. The Kruskal-Wallis H and Tukey post hoc tests were used to assess the distribution of the PI values among the three categorized MCI groups.

Results

There were a total of 65 subjects who participated in this study. Table 1 shows that their ages, post-menopausal periods, and cortical bone densities (mean \pm standard deviation) were 64.88 \pm 7.62 years, 167.86 \pm 97.17 months, and a density of 80.60 \pm 19.49, respectively. The p-values indicated neither age nor amenorrhoeic periods were related to the PI values. The kappa analysis showed some high intra- and inter-

agreements between the first and second radiographic assessments.

By using the mandibular index²³, 26, 32, and 7 subjects were categorized as C1, C2, and C3, respectively. Figure 2 shows the cortical bone PI values among the three classifications. A significant association (p < 0.05) between the PI values and the MCI, together with the MCI and the T-scores of the hip bones were detected.

The PI values calculated from the ROI of the cortical bone were different among the three classifications. The mean values were 37.96, 33.28, and 13.29 for normal, osteopenic, and osteoporotic groups, respectively (χ^2 (2) = 9.47 and *p* = 0.009).

Parameter	Subject number	Max.	Min.	Mean	SD
Cortical bone pixel intensity	65	140.50	50.10	80.60	19.49
Age (years)	65	86.00	55.00	64.88	7.62
Amenorrheic periods (months)	65	393.00	1.00	167.86	97.17

 Table 1. Characteristics of the subjects.



Figure 2. Box-and-whisker plots illustrate the values of the cortical bone pixel intensity (ordinate), and the mandibular cortical indices (abscissa). Normal cortex (bilateral even and sharp endosteal cortical margins), mild-tomoderate cortex erosion (bilateral one or three endosteal cortical residues), and severe cortex erosion (heavy endosteal cortical residues and porous cortex) are designated as C1, C2, and C3, respectively. Three black horizontal lines at the top, bottom, and between the top and the bottom of each blue box indicates the data's first quartile, third quartile, and mean, respectively. The two horizontal lines that are perpendicular above and below each box, indicates the maximal and minimal values, respectively.

Discussion

Osteoporosis causes a decrease in bone density and increases the risk of fractures in women during their menopausal age. The diagnosis of osteoporosis relies on the BMD assessment, by using a DXA machine, but the use of dental panoramic images, are more cost effective and are a commonly used in regular examination of patients. Amona several radiomorphometric indices obtained from the images, the MCI classification is recommended for the detection of osteoporosis, due to its practicality and accuracy. The precise information gleaned from some images in regards to the reduction of BMD, helped the PI to overcome the limitation of the conventional MCI assessment.24

Klemetti and associates developed the MCI index, which could assess the appearance of the mandibular endosteum.²³ Due to bone loss being predominantly found in the cortical bones which is associated with age 25, the detection of the BMD reduction at the mandibular cortical bone is possible by using the PI values. This study chose to use the PI value measurements over the conventional MCI assessments, due to their accuracy and the fact that we found a correlation between the PI values and the MCI classification. Some significant inter-classification differences in the PI values were revealed between the normal and the osteoporotic groups. A strong correlation between the classifications and the T-scores from the DXA machine, illustrated the detectability of bone mineral loss by using the MCI and the PI values that corresponded with a conclusion in the systematic review.²⁶

A significant difference in the PI values of the mandibular cortical bone was observed between the normal and osteoporotic groups. The PI reductions in the bone coincided with those reported in other investigations that used the PI and ROI determinations.^{27, 28} However, some exceptions may exist in the ROI due to an unclear mental foramen (black oval in Figure 1). The average PI values were calculated by a summation of the overall PI in an ROI image, and divided by the number of pixels in it. Changes in the ROI location and area could result in the alterations of the PI values. A difficulty in locating ROI sometimes creates the need to investigate the calculations of the PI values, by using a standardized procedure or an image processing algorithm.

The female BMD changes are related to the women who are aged between 60 and 70 years old (or over), have a faster rate of bone loss.²⁵ Despite the relevant variables (the menopausal periods and age) and the predictability of the female BMD reductions caused by aging, the results in this study showed a lack of correlation between aging, and the PI values measured at mandibular cortical bone. A limited sample size may contribute to this phenomenon and expose the weakness of conclusions. Significant influences of gender, weight, and calcium intake can affect the BMD documented.^{29, 30} have also been While comprehensive records of the patient's aforementioned factors, are necessary to provide a better understanding of their conditions.³¹

Conclusions

The digital panoramic radiographs that were taken from the osteoporotic subjects, showed a reduction in bone density as a negative correlation of the PI values from the mandibular cortical bone. The PI values were found to be related to three categorized MCI measurements. Due to the limited number of our subjects, a correlation between their age and menopausal periods was unverifiable. Completed records of all the factors relating to osteoporosis, are obligatory to be able to obtain a definite conclusion.

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Declaration of Interest

The authors have no conflicts of interest relevant to this article.

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