치의학박사 학위논문

Development and validity evaluation of a screening program for Korean osteoporotic women using mandibular cortical width on panoramic radiograph

파노라마방사선영상의 하악 피질골 두께를 이용한 한국 여성의 골다공증 스크리닝 프로그램 개발과 유용성 평가

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ABSTRACT

Development and validity evaluation of a screening program for Korean osteoporotic women using mandibular cortical width on panoramic radiograph

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Purpose

The purpose of this study was to develop and evaluate a screening program for Korean osteoporotic women using mandibular cortical width (MCW), which has been used for bone mineral density (BMD) assessment on panoramic radiographs.

Materials and Methods

A computer-based program was developed in order to measure the MCW automatically on panoramic radiographs. To identify changes in the MCW value according to the head position, panoramic radiographs were taken with 5 different vertical angulations using a head phantom. Normality test was performed among the MCW values measured from the panoramic radiographs of 250 young women. After a normal distribution was confirmed, the threshold corresponding to −2.5 standard deviations (SDs) was determined. The determined value was applied to the panoramic radiographs of 70 female subjects with a known femur BMD value, and the sensitivity, specificity, and accuracy were calculated. Additionally, a cut-off value for screening was obtained from a receiver operating characteristic (ROC) based on the data from these 70 female subjects.

Results

There was no statistically significant difference in the MCW with a change of vertical angle of the head phantom (Kruskal-Wallis test, P=0.406). Analysis of the MCW in the panoramic radiographs of young females showed a normal distribution (P=0.074). The threshold value corresponding to −2.5 SD was 2.46 mm. When this value was applied to patients with a known femur BMD value, the sensitivity, specificity, and accuracy were

60.0%, 96.7%, and 91.4%, respectively. The area under the ROC curve was 0.947 (95% confidence interval 0.894-0.999, P=0.000). The cut-off value obtained from the ROC curve was 3.32 mm.

Conclusion

In conclusion, it is suggested that the developed computer-based screening program for osteoporosis may have a validity in Korean women. If the cut-off value would be obtained from a big-data study, it could be used to screen for osteoporosis in patients who have undergone panoramic radiographic imaging in dental clinics.

Key words: Panoramic Radiograph, Osteoporosis, Mandible, Bone Mineral Density, Screening

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I. Introduction

1. Background

Osteoporosis is defined as "a disease characterized by low bone mass and microarchitectural deterioration of bone tissue, leading to enhanced bone fragility and a consequent increase in fracture risk".[1] Osteoporosis is asymptomatic, and it is often detected after a fracture, meaning that it is important to screen for it before a fracture takes place.[1] Meanwhile, osteoporosis is also defined based on bone mineral density (BMD) measurements.[1] Osteoporosis occurs when the amount of bone mineral is reduced; the diagnostic challenge is to establish an appropriate standard for assessing bone reduction. Many previous studies have obtained threshold values from young healthy adults, and this is also the approach used to define the T-score, which is applied in dual energy X-ray absorptiometry (DXA).[2] The World Health Organization criteria based on young adults for osteoporosis in women are as follows:[1] normal – a value for BMD within 1 standard deviation (SD) of the young adult reference mean, low bone mass (osteopenia) – a value for BMD more than 1 SD below the young adult mean but less than 2.5 SD below this value, osteoporosis – a value for BMD 2.5 SD or more below the young adult mean, and severe osteoporosis (established osteoporosis) – a value for BMD more than 2.5 SD below the young adult mean in the presence of one or more fragility fractures.

Methods of measuring bone mass or density include conventional skeletal radiography, radiographic photodensitometry, radiogrammetry, single-energy absorptiometry, dual-energy absorptiometry, DXA, quantitative computed tomography, photon-scattering methods, neutron activation analysis, and ultrasound evaluation of bone.[1] DXA is widely used because it is a convenient, noninvasive method and the radiation dose is smaller than that of natural background radiation.[3] However, it is not suitable as a screening tool because the equipment is expensive and not available in all clinics.

If the possibility of osteoporosis can be predicted using the panoramic radiographs taken of most patients who visit a dental clinic, it would be very helpful for individuals, and for society as a whole, in economic terms and convenience. In particular, patients who do not feel the need for bone density testing because they have no symptoms can be referred for additional testing if osteoporosis is predicted to be present in panoramic radiography. In fact, many studies have investigated the relationship between panoramic radiography and osteoporosis. In the first such study, a densitometric study was performed to evaluate bone density by attaching a nickel step wedge to a cassette.[4] Bras et al.[5] suggested that the cortical bone thickness at the mandibular angle (gonial index; GI) can be used as a diagnostic parameter for metabolic bone loss, and in 1991, Benson et al.[6] introduced the panoramic mandibular index (PMI), in which the mandibular cortical width (MCW) was divided by the distance from the superior or inferior margin of the mental foramen to the lower border of the mandible to compensate for the magnification of the panoramic radiography. The PMI is not related to the mineral status of the skeleton, but it can be used as an indicator, depending on the deviation from the average PMI of the population.[7]

Klemmetti et al.[8] published the mandibular cortical index (MCI) which was a morphometric index of the cortical bone, and they demonstrated that it was subjective but highly reproducible. Another study found that the number of remaining teeth in elderly women was closely related to the possibility of thoracic spine fracture.[9] However, the direct cause of tooth loss is local periodontitis, rather than systemic factors. Although osteoporosis is more likely to be associated with tooth loss for individuals with the same periodontal condition, it is difficult to use as a screening index because it is an aggravating factor, not a cause.[10] Additionally, although alveolar bone tends to decrease with increasing age, alveolar bone loss is not useful for BMD assessment.[11] In 1999, Ledgerton et al.[12] measured the GI, MCW, PMI, MCI, and the cortical width at the antegonion (antegonial index; AI) as a new index, and investigated the relationship between these indices and age, and the repeatability of the indices. All indices were significantly related to age, but the repeatability of the GI was poor and its practicality was low.[12] It was also found that the AI was difficult to use as a predictor of osteoporosis.[13]

According to a meta-analysis of the MCI, MCW, and PMI, the PMI had higher sensitivity than MCW, although MCW showed higher specificity.[12] However, some studies have addressed the problem of the identification of the mental foramen and of a weak association of the PMI with BMD and osteoporosis.[14–16] MCW was more accurate for excluding patients with a normal BMD when the threshold value was 4 mm or more.[12] The MCI had a very wide range of sensitivity and specificity across studies.[17] The MCW and MCI were found to be significant in postmenopausal women,[14] and chi-square automatic interaction detection analysis showed that MCW was a better predictor than the MCI.[18] Other studies have shown that the reproducibility and inter-observer variability of the MCI were poor.[19] However, experienced operators who received training showed more significant results.[19]

Thus, MCW is a useful measurement method, and it has been used in the OSTEODENT study in Europe. According to a report published in 2007, when the threshold value of 3 mm proposed by Devlin and Horner[20] was used as a diagnostic threshold, the sensitivity was 41.0%–59.6% and the specificity was 81.8%–90.3%.[21] Many researchers have also agreed about the usability of MCW, which has fewer limitations.[18,22,23]

2. Recent studies

Recently, many studies have been conducted to measure MCW using computers. In one such study, the images were processed using a thresholding algorithm and filtering method, and the length was measured by identifying the cortical margin.[24] The determination of the mental foramen and the measurement of the distance between the superior and inferior cortical margin were performed manually.[24] In the process of determining the mental foramen, the operator's experience may have influenced the outcome, and the overlap of the hyoid bone was a major limitation.[24]

The active shape model (ASM) was also developed. The endosteal and periosteal borders of cortical bone between the mental foramen and the antegonial region were manually traced, and a computer program was then trained on various forms to find the most appropriate form for the actual patient.[25] However, the ASM had the limitation that the superior eroded cortex was not well defined on panoramic images.[26] When the ASM was combined with the active appearance model, the diagnostic accuracy was improved.[26] In 2012, Kavitha et al.[27] developed a kernel-based support vector machine method that enhanced the panoramic images to determine the boundary of the cortex from the mental foramen to the mandibular angle region and continuously measured all MCWs within the region of interest.[23]

3. Purpose

The aim of this study was to develop a screening program for osteoporosis using MCW obtained from panoramic radiographs and to evaluate its validity. In this study, the MCW of young women was measured and analyzed with a new computer-based program. The MCW value equal to −2.5 SD of the mean value of young women from 20 to 39 was determined and used as a threshold similar to the T-score, which is frequently used to diagnose osteoporosis, as mentioned above. In addition, receiver operating characteristic curve analysis was also investigated to evaluate the program as a screening purpose.

II. Materials and Methods

1. Development of the measurement program

Using MATLAB R2015b (Mathworks, Natick, MA, USA), a program was developed to measure the MCW. The MCW was defined as the distance between the superior and inferior points of the cortical bone below the mental foramen (Figure 1). Since it was difficult to identify the location of the mental foramen completely automatically, an oral and maxillofacial radiologist determined the location of the mental foramen, fixed the point, and then extended the line beyond the inferior margin of the mandible to analyze the profile of the corresponding line. The inferior point was set as the point where the line profile differed the most abruptly. The superior point was set as the nearest pixel to the mental foramen with the highest density in the line profile. This new method was simply called the pixel density method. The developed program in this study allowed the observer to zoom in on the region of interest. The program also displayed the measured lines on the image, which provided the useful function of confirming the correct measurements for the observers (Figure 2). Using these functions, observers could reduce false measurements due to the noise observed in the cortical bone. To obtain more reasonable data than the MCW value measured in one line, the mean and SD of the MCW, corresponding to the width of the adjacent 30 pixels, were automatically calculated. The panoramic radiographs used in the program were obtained with an Orthopantomograph OP100 apparatus (Instrumentarium Dental, Tuusula, Finland) and Fuji computed radiography system (FCR 5000, Fuji film Co., Tokyo, Japan). The reading gray scale of the FCR 5000 reader was 10 bits/pixel. The pixel size (spacing) and a pixel count were 0.15 × 0.15 and 1670 × 2010, respectively. The sampling rate was 6.7 pixels/mm. Therefore, the MCW value measured as the number of pixels was divided by 6.7 to convert into millimeters (Eq. 1).

$$Mandibular\ cortical\ width\ (mm) = \frac{Distance\ measurement\ value\ (pixel)}{Factor\ (pixels/mm)} \qquad \text{(Eq. 1)}$$

2. Phantom analysis: measurement of MCW according to the head position

To investigate whether the MCW value could be influenced by head tilt in panoramic radiography, panoramic radiographs were taken with various vertically tilted head positions using a transparent X-ray head phantom with a soft tissue replica (X-ray phantom, head; product number 7280; Erler Zimmer Co., Lauf, Germany) and tongue depressors (Figure 3). The various vertical head positions were set using tongue depressors that were inserted at the posterior part of the bottom of the head phantom. Five tongue depressors, each with a thickness of 1.6 mm, were piled up to form 5 conditions: −6.7°, −3.4°, 0° (parallel to the Frankfort horizontal line), 3.2°, and 6.4°.

In order to investigate whether the experimental results differed by equipment type, the experimental images were acquired in 5 different angular conditions using 2 pieces of panoramic radiography equipment (Figure 4): a digital radiography (DR) apparatus, Pax-I (Vatech, Hwaseong, Korea) and a computed radiography (CR) apparatus, Orthopantomograph OP100 and FCR 5000. MCW was measured under each condition, and the Kruskal-Wallis test was performed in IBM SPSS version 23 (IBM Corp., Armonk, NY, USA).

3. Measurements of MCW in young women

To determine the value corresponding to −2.5 SD in the distribution of MCW in young women with reference to the definition of the T-score, the MCW was measured in 250 panoramic radiographs obtained from 20- to 39-year-old female patients who visited the Seoul National University Dental Hospital. Panoramic radiographs were acquired using the Orthopantomograph OP100, which was the same equipment used for the program. A general-purpose FCR imaging plate (IP ST-VI, Fujifilm Co., Tokyo, Japan), a FCR standard cassette measuring 10″ × 12″ (25.7 × 30.5 cm) (IP cassette Type CC, Fujifilm Co., Tokyo, Japan), and an FCR 5000 reader were used to obtain the panoramic radiographs.

The 250 radiographs in the Digital Imaging and Communication in Medicine (DICOM) format were selected in an anonymized and randomized manner. The exclusion criteria were poor image quality and the presence of lesions or surgical defects affecting the mandibular cortical bone. Since a region to measure the MCW was displayed on the image at the time of measurement, the measured MCW lines in the region were checked, and if the measurement was erroneous, the MCW was measured again. A normality test (the Kolmogorov-Smirnov test) was performed to ensure that the values were normally distributed. When a normal distribution was confirmed, the threshold corresponding to −2.5 SD was determined.

4. Application of the determined value to patient images as a diagnostic program

In order to assess whether the threshold value determined above was appropriate, the MCW was measured in patient images obtained from Kyungpook National University Hospital. Seventy female patients with both a T-score of DXA for the femur site and a panoramic radiograph were selected. The mean age of the patients was 61.6 years old (range, 26.9-95.0 years).

The panoramic radiographs had been taken with an Orthopantomograph 100D (Instrumentarium Dental, Tuusula, Finland), which is a DR apparatus with a resolution of 1670 × 2210 pixels and a pixel size of 96 × 96 μm^2, resulting in 10.41 pixels/mm. The MCW value measured by the program was converted by Eq. 1. The distance of the smaller MCW among the measured values on both sides was used as the result to be compared. When the hyoid bone was overlapped or the mandibular cortex was affected by the lesion, the value measured on the opposite side was used.

When this value was −2.5 SD or less than −2.5 SD of the mean value obtained from young women, it was considered to indicate osteoporosis, and the presence of osteoporosis diagnosed by the femur T-score was analyzed as the gold standard. Based on the femur T-score, there were 10 patients with osteoporosis, 32 patients with osteopenia, and 28 patients with normal findings. The gold-standard group was divided into patients with osteoporosis and patients without osteoporosis. Thus, when the T-score was −2.5 or less than −2.5, it was set as a positive gold standard, and when it is more than −2.5, it was set as a negative gold standard. The measured value and the gold standard were compared, and the sensitivity, specificity, accuracy, prevalence, positive predictive value, negative predictive value, odds ratio, and relative risk values were calculated.

5. Receiver operating characteristic curve analysis as a screening program

Additionally, a cut-off value and area under the curve (AUC) value were obtained from receiver operating characteristic (ROC) curves using measured MCW and T-score data from the 70 female patients discussed above. The results of the ROC curve analysis show several pairs of sensitivity and specificity as the MCW changed. The cut-off value was defined as the MCW that had the smallest results calculated by the following equation (Eq. 2).[28]

$$(1 - sensitivity)^2 + (1 - specificity)^2 \quad \text{(Eq. 2)}$$

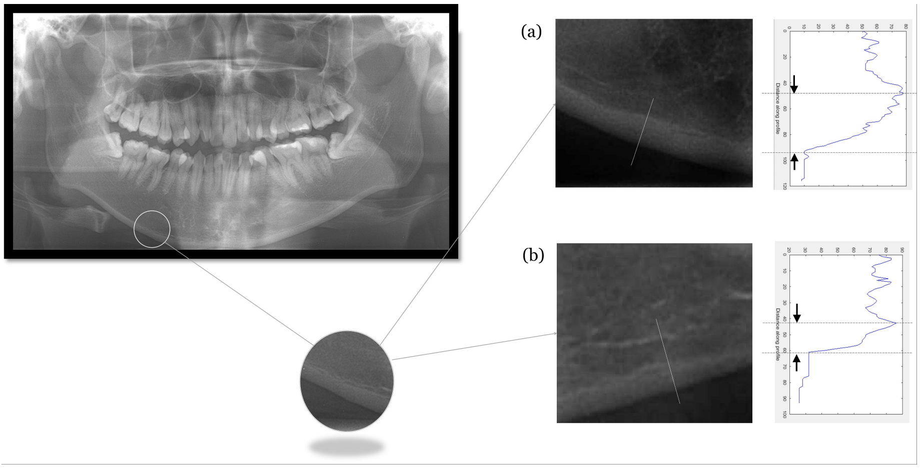


Figure 1. Mandibular cortical width (MCW) is measured in the line profiles of the cortical bone below the mental foramen in panoramic radiographs. (a), (b) The distance between the point where the density rapidly decreases and the point with the highest pixel density is the proper measurement for the MCW (arrow).

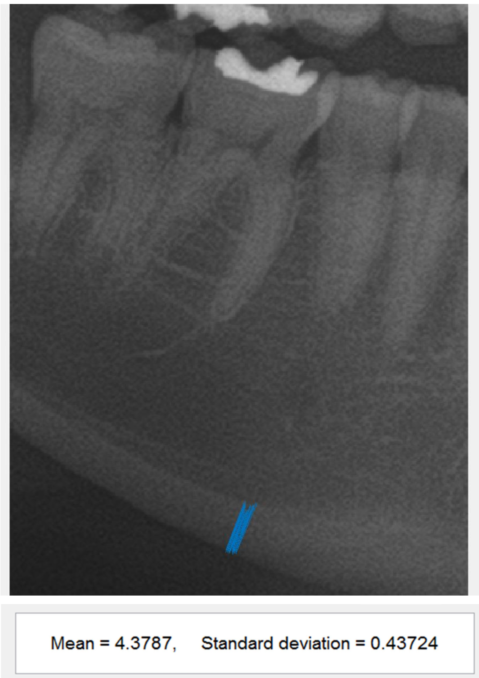


Figure 2. The mandibular cortical width is presented as the mean and standard deviation from the adjacent 30 pixels using the developed program.

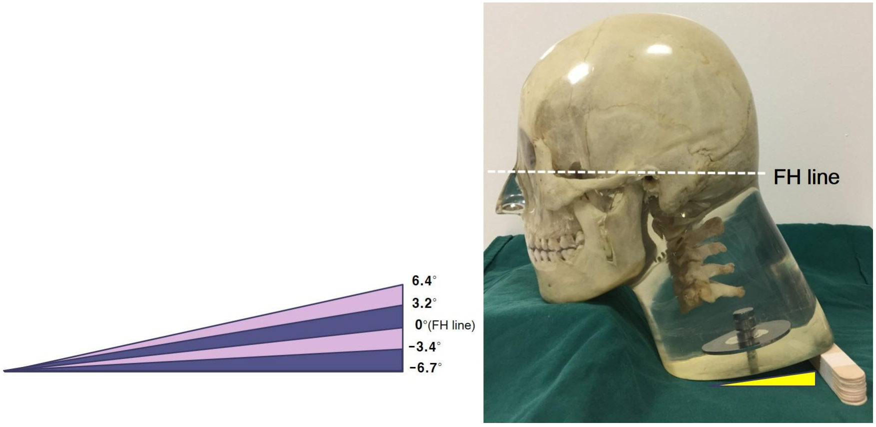


Figure 3. Vertical angulations are changed under each acquisition of a panoramic radiograph by lifting the rear of the phantom using tongue blades.

(a)

(b)

Figure 4. Two pieces of panoramic radiography equipment are used in phantom analysis. (a) Pax-I, Vatech, Hwaseong, Korea (b) Orthopantomograph OP100, Instrumentarium Dental, Tuusula, Finland

III. Results

In the phantom analysis with changes in the vertical angle of the head, both CR and DR panoramic images showed no significant differences in MCW in the 5 different angular conditions (Kruskal-Wallis Test, P=0.406). This meant that even if the head position was slightly changed vertically, it did not affect the MCW on the panoramic radiographs. The analysis of MCW in the panoramic radiographs of individuals in their 20s and 30s showed a normal distribution (P=0.074) (Figure 5). The threshold value of −2.5 SD was 2.46 mm (Figure 6). This value was applied to panoramic radiographs of 70 female subjects with known femur BMD values, and the sensitivity and specificity were 60.0% and 96.7%, respectively. The accuracy was 91.4% (Table 1).

The positive and negative predictive values were 75.0% and 93.5%. In other words, among the patients who were found to have osteoporosis based on an MCW value of 2.46 mm or less, the probability of having osteoporosis in reality, as confirmed by DXA measurements, was 75.0%, and among the patients who were found not to have osteoporosis based on the MCW measurements, the probability of not having osteoporosis in reality was 93.5%. The probability that a patient who actually had osteoporosis showed an MCW of 2.46 mm or less was 43.5

times than that of a patient without actual osteoporosis, as indicated by the odds ratio. With reference to the result of relative risk, when the MCW was 2.46 mm or less, the possibility of actual osteoporosis was 11.6 times higher than when the MCW was greater than 2.46 mm.

The cut-off value using ROC curve to evaluate screening validity was 3.32 mm (Table 2), which was higher than 2.46 mm. The AUC was 0.947 (95% confidence interval 0.894-0.999; *P*=0.000), which was excellent (0.90-1.00) (Figure 7).

(a) (b)

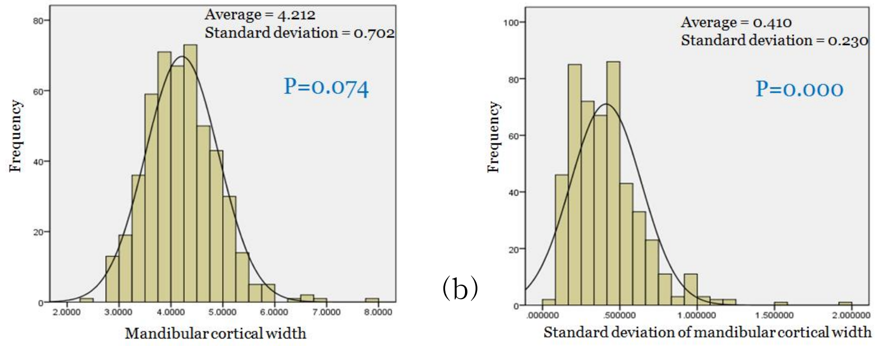


Figure 5. (a) The distributions of the mandibular cortical width (MCW) shows a significant normal distribution in females. (b) The standard deviation of MCW does not show a significant normal distribution.

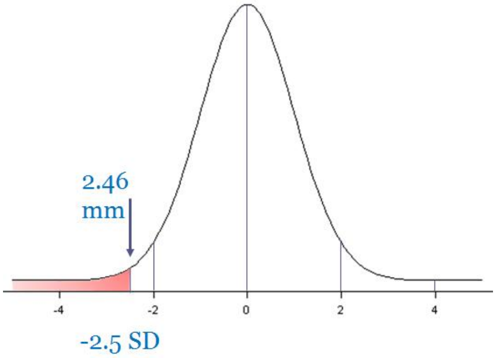


Figure 6. The −2.5 SD threshold value in females is 2.46 mm (SD: standard deviation).

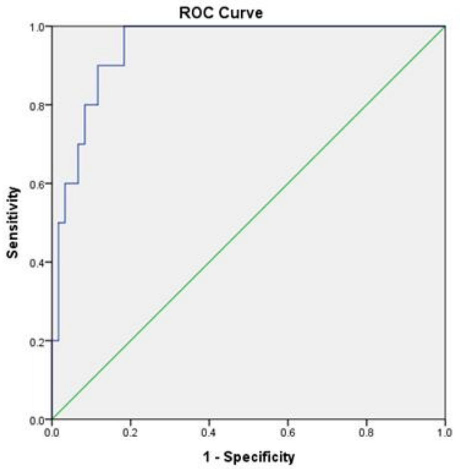


Figure 7. The area under the curve of the receiver operating characteristic (ROC) curve is 0.947 (95% confidence interval 0.894-0.999; P=0.000), which is excellent (0.90-1.00).

Table 1. Validity test of the determined threshold value (2.46 mm) for a diagnostic program using known femur bone mineral density values of 70 female patients as a gold standard

Sensitivity	60.0%	Positive predictive value	75.0%
Specificity	96.7%	Negative predictive value	93.5%
Accuracy	91.4%	Odds ratio*	43.5
Prevalence	14.3%	Relative risk	11.6

* Odds ratio = (true positive × true negative) / (false positive × false negative)

Table 2. Comparison of sensitivity and specificity of different mandibular cortical width (mm) to determine a cut-off value for a screening program using known femur bone mineral density values of 70 female patients as a gold standard

Positive if less than or equal to (mm)	Sensitivity (%)	Specificity (%)
1.03	0.0	100.0
2.05	10.0	100.0
2.20	20.0	100.0
2.36	20.0	98.3
2.40	30.0	98.3
2.42	40.0	98.3
2.44	50.0	98.3
2.46	50.0	96.7
2.57	60.0	96.7
2.69	60.0	95.0
2.79	60.0	93.3
2.89	70.0	93.3
3.02	70.0	91.7
3.11	80.0	91.7
3.16	80.0	90.0
3.26	80.0	88.3
3.32*	90.0	88.3
3.34	90.0	86.7
3.42	90.0	85.0
3.51	90.0	83.3
3.54	90.0	81.7
3.58	100.0	81.7
3.62	100.0	80.0

* Cut-off value

IV. Discussion

In this study, a new screening program for osteoporotic women was developed. In the presence of eroded residue in the superior margin of the endosteal cortex in osteoporotic patient, the limitation of a previous method[26] that the superior eroded cortex was not well defined on panoramic image was improved. When such residues were present, the results varied depending on the pixel density of the residue (Figure 8). Taguchi et al.[22] suggested that a trabecular bone tail, which is most commonly seen in young patients with a normal BMD, is often mistaken for an eroded cortex. However, when the pixel density of the residue was higher than that of superior cortex (Figure 8b and c), the measured MCW value tends to be higher than the determined threshold value, meaning that the patient is normal. This overestimation did not affect the result of the diagnosis because it was a normal trabecular bone tail rather than the eroded cortex. In other words, the eroded cortex in osteoporosis patients had a low pixel density value and the trabecular bone tail of normal patient had a high pixel density. Therefore, it seems to be possible to distinguish between a normal trabecular bone tail and an eroded cortex using the pixel density method. In addition, the fact that the measured area is displayed on the image at the time of measurement allows the intuitive identification of incorrect measurements.

However, it was difficult to measure the MCW when the hyoid bone overlapped with the cortical bone. Nevertheless, there were some measurable cases in our study (Figure 9), in which the hyoid bone partially overlapped with the upper part of the cortical bone, resulting in meaningful overestimation of the results (Figure 10a and b). When the cortex was completely overlapped by the hyoid bone (Figure 10c), it could not be resolved even by making manual measurements; the only way of solving this issue was to obtain another image in which the hyoid bone did not overlap.

In panoramic radiography, the angle of the head is slightly different at each acquisition. According to a previous study investigating how horizontal and vertical length measurements changed when the head position was changed from 1° to 4° vertically and horizontally in panoramic radiography, significant differences were found in horizontal measurements at the canine and the first molar region when the skull was moved from side to side.[29] However, there was no significant difference in the horizontal measurements when moving downward from the Frankfort horizontal plane. When moving upward, there was a significant difference in the horizontal measurements.[29] The vertical measurements did not significantly differ across all vertical and horizontal changes.[29] MCW is a vector that includes both horizontal and vertical measurements, with the vertical components being more relevant than the horizontal components. Although MCW was not included in that previous study, our study did not show a significant difference according to vertical angle changes. Moreover, according to Taguchi's paper, which was written in Japanese, the coefficient of variation due to the position or operator was less than 2% in MCW measurements.[30]

The MCW measured in our study in young female subjects showed a normal distribution, and the value corresponding to −2.5 SD was 2.46 mm. The determined value was applied to panoramic radiographs of 70 women with known femur BMD. The sensitivity and specificity were 60.0% and 96.7%, respectively, and the sensitivity was somewhat low. Because patients with osteopenia were also considered a negative group, the number of osteoporosis-positive patients was less than that of osteoporosis-negative patients. The sensitivity is expected to increase in groups with more osteoporosis patients.

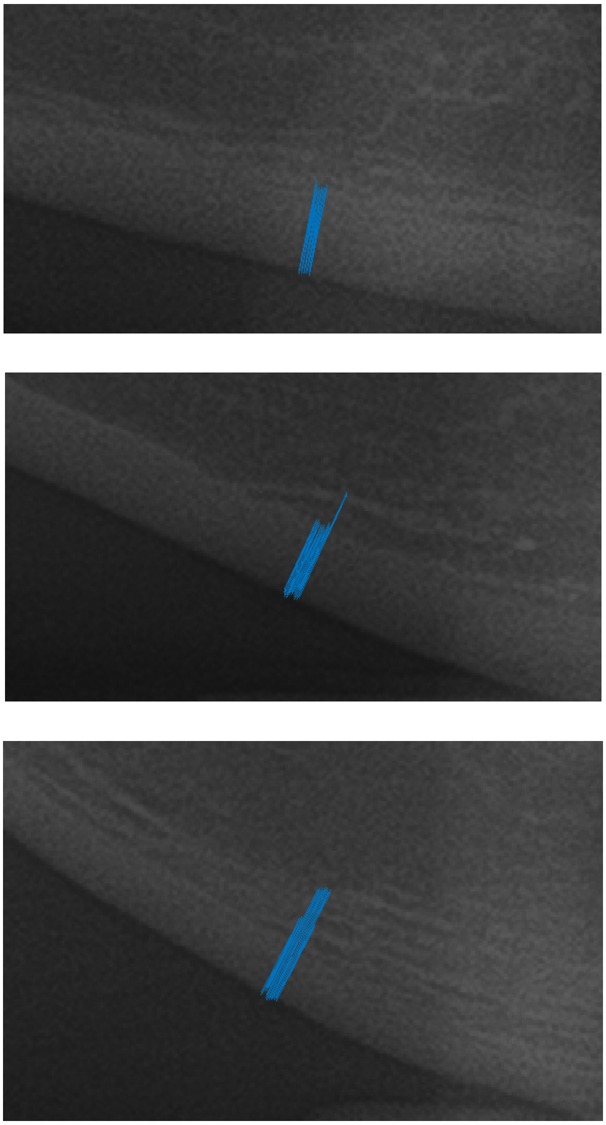
The cut-off value from the ROC curve was 3.32 mm, and the sensitivity and specificity at that value were 90.0% and 88.3%, respectively. The definition of the T-score used to obtain 2.46 mm is a criterion used for diagnostic purposes. Therefore, the threshold value (2.46 mm) was lower than the cut-off value (3.32 mm) for screening purposes. Moreover, the sensitivity of the determined threshold (60%) must be less than that of the cut-off value (90%).

Arifin et al.[24] reported that the cutoff threshold obtained using computer-aided measurements was lower than was obtained using manual measurements. In their study, the manual measurement was 3.91 mm and the computer-aided measurement was 3.16 mm, based on an analysis of the subjects for whom the BMD of the femoral neck was known.[24] Since the human eye has nonlinearity, while computers exhibit linearity, it has been claimed that there is a difference in the position of the determined margin.[24]

Previous studies[7,9,11,13,14,16,21,24] have focused primarily on women, and another study reported that MCW was not a meaningful parameter in men.[31] According to the results of another study, the MCW of males decreased slowly with age, and therefore it seemed that there was no marked difference in the male group.[32] Moreover, fracture incidence among women increases after age 45, but it increases after 75 years for men.[1] Because screening is important for both men and women in the elderly, more research on men is needed.

Since bone remodeling disorders such as osteoporosis occur first in trabecular bone, rather than in cortical bone,[1] bone changes in the cortical bone can mean that the condition has already progressed to involve osteoporotic changes. However, osteoporosis is often asymptomatic, and even if it is discovered after it has progressed, it can be useful for patients who are not aware of their condition.

The DXA value of each skeletal region is different, as research has indicated that the ability to identify osteoporosis using femur DXA values is lower than when spine DXA is used.[33] Since femur BMD is not perfect as a gold standard, there is a limitation in accurately assessing the validity of MCW. If there was a BMD measurement method that could be used as a gold standard for the mandibular cortex, better results could be obtained. Although MCW has some limitations in the diagnosis of osteoporosis, its role as a screening parameter is sufficient, and may be helpful for improving screening efficiency when combined with other BMD assessments.



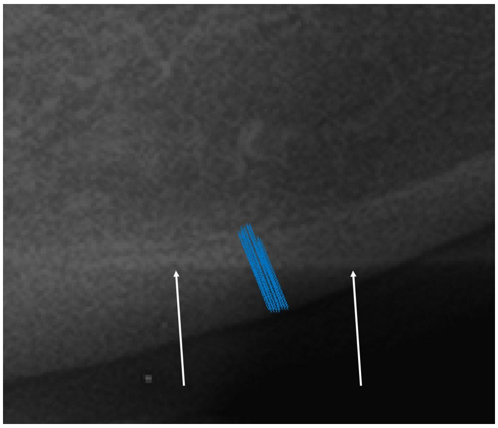
(a)

(b)

(c)

Figure 8. (a) Even though eroded residues are present, there is no overestimation. (b) Only one line is measured because of the trabecular bone tail. (c) Overestimation of the residues. The results depend on the density of the residues.

(a)



(b)

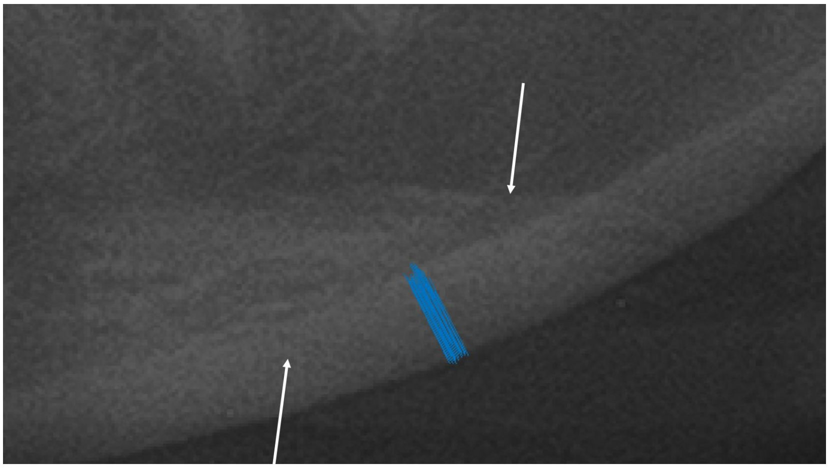
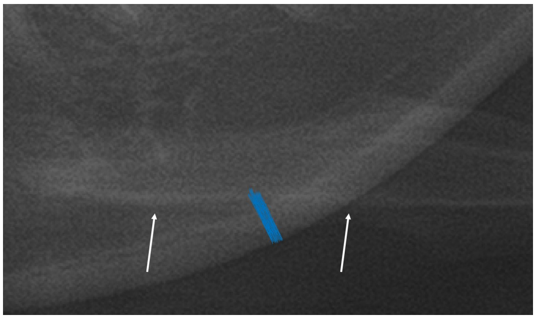
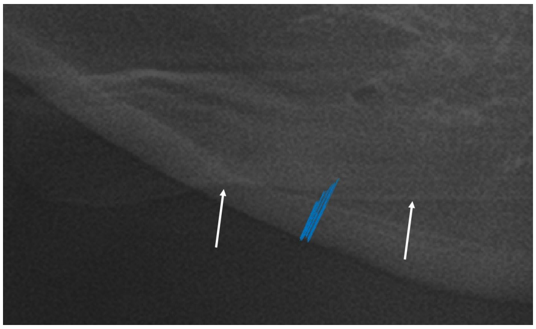


Figure 9. (a), (b) Two examples of measurable cases in which the hyoid bone (arrows) overlapped with the cortical bone.

(a)



(b)



(c)

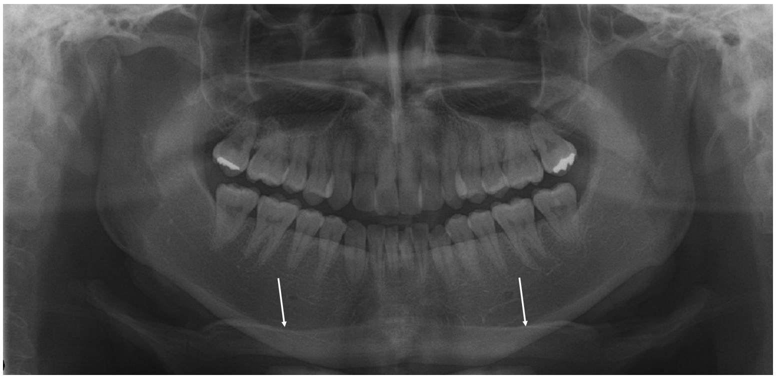


Figure 10. (a), (b) When the hyoid bone overlap partially over the upper part of the cortical bone, the MCW is overestimated, affecting the results. (c) When the cortex is completely overlapped by the hyoid bone, the MCW cannot be measured, even though manual measurements. MCW, mandibular cortical width.

V. Conclusion

The developed program in this study was simple and allowed easy identification of the measured region. Because the location and shape of the mental foramen varied greatly, the use of a semi-automated system is more practical than using a fully automated system. In conclusion, our computer-based program for osteoporosis screening is valid in women. If the cut-off values were calculated using a larger data set, it would be possible to screen for osteoporosis in patients who have undergone panoramic radiography at a dental clinic.

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국문요약

파노라마방사선영상의 하악 피질골 두께를 이용한 한국 여성의 골다공증 스크리닝 프로그램 개발과 유용성 평가

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목 적

파노라마방사선영상의 하악 피질골 두께는 많은 연구에서 골밀도 평가에 이용되어 왔다. 이 연구의 목적은 하악 피질골 두께를 이용하여 한국 여성의 골다공증 스크리닝 프로그램을 개발하고 그 유용성을 평가해 보는 것이다.

재료 및 방법

이 연구에서는 파노라마방사선영상에서 자동으로 하악 피질골 두께를 측정하는 컴퓨터 기반 프로그램을 개발하였다. 또한 두부의 위치에 따라 하악 피질골 두께가 변화하는지 확인하기 위하여 두부 팬텀의 수직 촬영 각도를 일정하게 변화시켜 5가지 조건에서 파노라마방사선사진을 촬영하여 분석하였다. 20-39세 여성 파노라마 방사선 사진 250매를 대상으로 하악 피질골 두께를 측정하고 정규성 검사를 시행하였다. 통계학적으로 정규분포를 나타내는지 확인한 후 -2.5 편차 (-2.5 SD)에 해당하는 임계치를 결정하였다. 이미 대퇴골에서 측정한 T-score 값이 있는 70매의 여성 환자 영상에 임계치를 적용하여 민감도, 특이도 및 정확도 등을 분석하였다. 또한 70명의 여성 환자 데이터를 이용하여 스크리닝을 위한 절단값 (cutoff value)을 산출하였다.

결 과

두부 팬텀을 이용하여 촬영 각도의 수직적 변화에 따른 하악 피질골 두께의 변화는 통계학적으로 유의미하게 차이가 나지 않았다 (Kruskal Wallis Test, P=0.406). 20-30대 여성 파노라마 방사선 사진 분석 시 하악 피질골 두께는 유의한 정규분포를 나타내었으며 (P=0.074), -2.5 SD에 해당하는 임계치는 2.46 mm 이었다. 골밀도를 알고 있는 여성 환자군에 적용 시 민감도는 60.0%, 특이도는 96.7%, 정확도는 91.4%이었다. ROC 곡선 아래의 면적(AUC 값)은 0.947 (95% 신뢰구간 0.894-0.999, P=0.000)이었고, ROC 곡선에서 구한 절단값은 3.32 mm 이었다.

결 론

결론적으로, 개발된 컴퓨터 기반 스크리닝 프로그램은 한국 여성에게 유용하다고 할 수 있으며, 더 많은 데이터를 기반으로 절단값을 산출한다면 치과에 내원하여 파노라마방사선영상을 촬영한 환자에게서 골다공증 스크리닝을 하는 것이 충분히 가능하게 될 것이라고 생각한다.

주요어 : 파노라마방사선영상, 골다공증, 하악, 컴퓨터 기반

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