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Is the panoramic mandibular index useful for bone quality evaluation?

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ABSTRACT

Purpose: The aim of this study was to determine whether the panoramic mandibular index (PMI) is useful for assessing bone mineral density. We also analyzed the potential correlations between PMI parameters and patient age.

Materials and Methods: Four observers measured the PMI of both sides of the mental foramen using a picture archiving and communication system and images in the Digital Imaging and Communications in Medicine format. They studied 300 panoramic radiographic images of patients belonging to the following age groups: 40-49 years, 50-59 years, 60-69 years, 70-79 years, and 80-89 years. The observers were allowed to zoom in or out and to adjust the contrast of the images. Further, they were instructed to record the reasons for any measurements that could not be made. Then, we conducted a reliability analysis of the measured PMI and assessed the correlations between different patient age groups and the 3 parameters used for determining the PMI from the available data.

Results: Among the 600 data items collected, 23 items were considered unmeasurable by at least 1 observer for the following 4 reasons: postoperative state, lesion, unidentified mental foramen, and alveolar bone loss. The intra-observer reproducibility of the measurable data was 0.611-0.752. The mandibular cortical width (MCW) decreased significantly as patient age increased.

Conclusion: PMI had limited usability when the margin of the mental foramen was not clear. In contrast, MCW, a parameter used for determining the PMI, had fewer drawbacks than the PMI with respect to bone mineral density measurements and exhibited a significant correlation with patient age. ***(Imaging Sci Dent 2017; 47: 87-92)***

KEY WORDS: Radiography, Panoramic, Bone density, Mandible

Introduction

Osteoporosis is a condition characterized by high susceptibility to fractures due to reduced bone mass and strength.[1] As the condition itself is practically asymptomatic, in many cases, it is detected after a fracture, which commonly occurs in the spine, wrist, or hip.[1] Hip fractures are significantly associated with morbidity.[1] Hence, it is important to diagnose osteoporosis prior to a fracture.

To diagnose osteoporosis, we need to measure the bone mass.[2] Some of the measurement methods used for this purpose are single-photon absorptiometry, dual-photon absorptiometry, quantitative computed tomography, and dual-energy X-ray absorptiometry (DXA).[2] Of these methods, DXA is the most widely used because of its short measurement time and low radiation dose.[3] However, DXA is expensive.[4] Therefore, as most people usually undergo panoramic radiography at a dental clinic, it will be economically beneficial if panoramic radiography is used for osteoporosis screening.

In this context, many studies have been conducted to establish a measurement index for screening osteoporosis by using information from panoramic dental radiographs. Radiomorphometric indices include the mandibular cortical index (MCI), gonion index (GI), antegonial index (AI), mandibular cortical width (MCW), and panoramic man-

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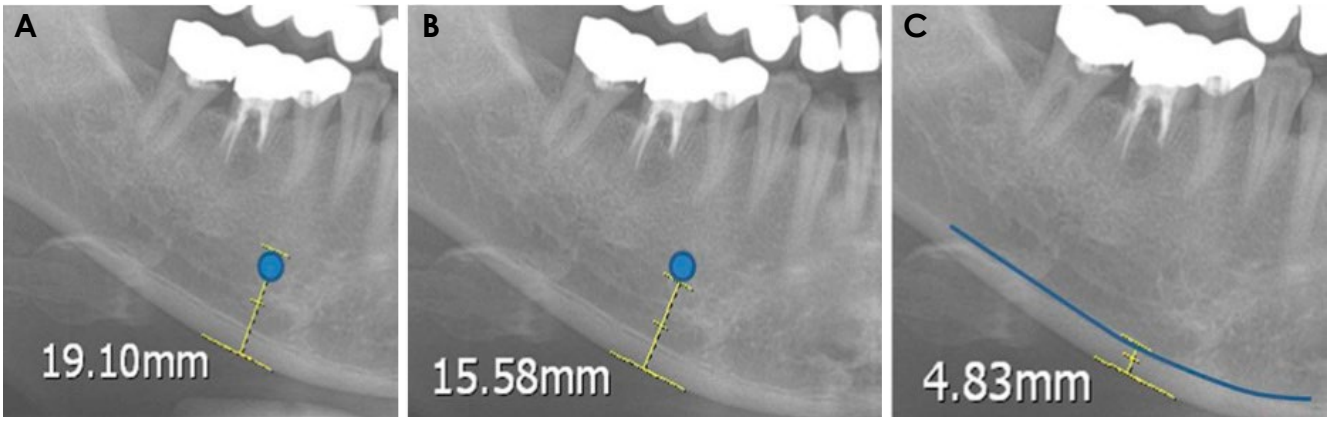

Fig. 1. A. Cropped panoramic radiograph shows the mental foramen marked with a circle and the distance measurement value. The distance between the superior margin of the mental foramen and the lower border of the mandible is 19.10 mm. B. The distance between the inferior margin of the mental foramen and the lower border of the mandible is 15.58 mm. C. The measured distance of the mandibular cortical width is 4.83 mm.

dibular index (PMI).[5,6] The MCI is used for classifying the shape of the mandibular cortex,[7] and the GI, AI, and MCW are used as a measure of the length of the corresponding region.[5]

The PMI, defined as the ratio of the MCW to the distance between the superior or inferior margin of the mental foramen and the inferior margin of the mandibular cortex, was introduced by Benson in 1991 to compensate for the vertical magnification of panoramic radiography.[6] It has been shown to decrease significantly with increased age in women.[6] In contrast, a previous study reported that the PMI tended to increase with age,[8] and the usefulness of the PMI is still controversial. Moreover, the location of the mental foramen and the boundaries of the mandibular cortical bone are often not clear in the panoramic radiographs of a relatively large number of patients.[9-11] Hence, the feasibility of measuring both the distance from the margin of the mental foramen and the MCW must be validated prior to the clinical use of the PMI as an index for screening osteoporosis.

The aim of this study was to determine whether the PMI is useful for assessing bone mineral density. We also assessed the potential correlations between the 3 parameters of the PMI and patient age.

Materials and Methods

This study was approved by the Institutional Review Board of Seoul National Dental Hospital. This was a retrospective study, conducted using 300 panoramic radiographs. The radiographs of 30 male and 30 female patients belonging to 5 different age groups (40-49 years, 50-59 years, 60-69 years, 70-79 years, and 80-89 years), who visited the Seoul National University Dental Hospital, were collected. We did not establish exclusion criteria, as the objective of this study was verification under actual conditions. Panoramic radiographs were acquired with an Orthopantomograph OP100 (Instrumentarium Dental, Tuusula, Finland). This is a computed radiographic imaging system (FCR-5000 reader, Fujifilm Co., Tokyo, Japan) with pixel count of 1670×2010. A total of 4 observers were recruited for the study: observers 1 and 2 were residents in oral and maxillofacial radiology, and observers 3 and 4 were graduating students of Seoul National University School of Dentistry. The 300 radiographs were shown to these 4 observers in the Digital Imaging and Commu-

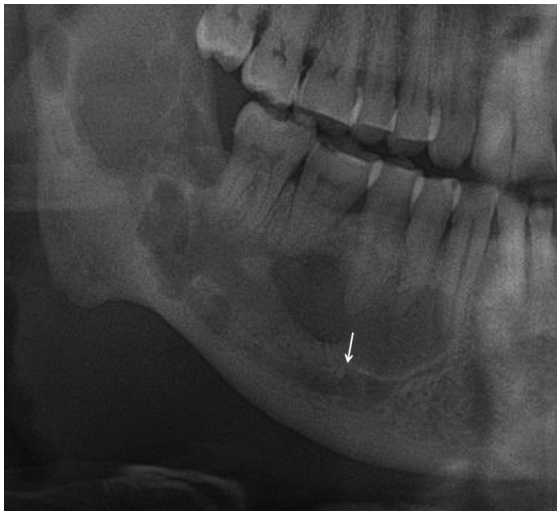

Fig. 2. The mental foramen is seen below the radiolucent lesion (arrow).

Fig. 3. A panoramic radiograph shows severe alveolar bone loss, and both sides of the mental foramen are identified near the alveolar crest level (arrow).

nications in Medicine (DICOM) format in an anonymized and randomized manner. The observers were allowed to zoom in or out and to adjust the contrast of the images. Further, they were instructed to record the reasons for any measurements that could not be made.

The following 3 distances were measured manually using the digital caliper function in the picture archiving communication system (INFINITT PACS, INFINITT Healthcare, Seoul, Korea): 1) distance between the superior margin of the mental foramen and the inferior border of the mandible (SL), 2) distance from the inferior margin of the mental foramen to the inferior border of the mandible (IL), and 3) mandibular cortical width (MCW) (Fig. 1). Two weeks after the initial measurements, all 4 observers repeated the measurements. The radiographs were randomized again and presented in a different sequence.

The following 5 data points were obtained from the measurements: 1) SL, 2) IL, 3) MCW, 4) superior PMI (sPMI = MCW/SL), and 5) inferior PMI (iPMI = MCW/IL).

Further, after excluding the unmeasurable data, we performed an interobserver intraclass correlation coefficient (ICC) analysis of sPMI and iPMI. Then, we calculated the intraobserver ICC value for each of the MCW, SL, and IL measurements. We also assessed the correlation between different age groups and the 3 parameters by using the data collected by observer 1, who was the most experienced observer. SPSS version 22 (IBM Corp., Armonk, NY, USA) was used to conduct the Pearson correlation test.

Results

Measurements were made from 300 panoramic radiographs. The measurements were made on both sides of the mental foramen, and therefore, 2 sets of 600 data items were collected over the first and the second trials. Among the data collected, 23 items were considered unmeasurable by at least 1 observer, for the following reasons:

Category 1: post-operative state; in the cases of 9 items, the mandibular cortex and the mental foramen were not visualized because of metal plate fixation after lesion removal or bone graft reconstruction.

Category 2: lesion; in the cases of 3 items, the mental foramen could not be visualized properly because of osteomyelitis or the presence of a cyst.

Category 3: unidentified mental foramen; in the cases of 2 items, the exact location of the mental foramen could not be identified.

Category 4: alveolar bone loss; in the cases of 9 other items, the mental foramen was exposed to the alveolar crest because of extreme alveolar bone resorption.

Of the 9 items from category 1, 4 items were unanimously considered unmeasurable, while the remaining 5 items were considered partially measurable by observers 3 and 4. One observer recorded different measurements in the first and the second trials; the observer appeared to have considered an idiopathic defect of the grafted bone to be the mental foramen.

With respect to category 2, there were differences among the observers, and 1 observer again provided different results for the first and the second trials. The location of the mental foramen was misdiagnosed because of the presence of lesions such as cysts or tumors (Fig. 2), and the detection of the mental foramen was even more difficult once it was infiltrated by a lesion.

Table 1. Age- and observer-specific interobserver intraclass correlation coefficient (ICC) values of the sPMI and iPMI

Age group, years	Observer	First sPMI	Second sPMI	First iPMI	Second iPMI
40-49	Total	0.794	0.839	0.793	0.865
	Resident	0.747	0.802	0.751	0.811
	Student	0.612	0.643	0.614	0.727
50-59	Total	0.724	0.765	0.722	0.791
	Resident	0.732	0.799	0.675	0.786
	Student	0.403	0.399	0.395	0.500
60-69	Total	0.792	0.824	0.783	0.810
	Resident	0.782	0.839	0.760	0.812
	Student	0.638	0.579	0.598	0.536
70-79	Total	0.812	0.857	0.800	0.856
	Resident	0.730	0.866	0.663	0.860
	Student	0.647	0.676	0.629	0.674
80-89	Total	0.882	0.904	0.866	0.899
	Resident	0.858	0.853	0.844	0.815
	Student	0.764	0.732	0.724	0.772

sPMI: superior panoramic mandibular index, iPMI: inferior panoramic mandibular index

Table 2. Intraobserver intraclass correlation coefficient (ICC) values of the sPMI and iPMI

	sPMI	iPMI
Observer 1	0.752	0.719
Observer 2	0.735	0.695
Observer 3	0.617	0.611
Observer 4	0.686	0.681

sPMI: superior panoramic mandibular index, iPMI: inferior panoramic mandibular index

For 1 item in category 3, although the mental foramen was detected with relative ease, observer 4 reported that it was unmeasurable. The results reported by observer 2 for the other item differed between the first and the second trials.

Measurability also varied for category 4, and most of the items for which the observers measured the distance from the superior margin of the mental foramen to the lower edge of the mandibular cortical bone (SL) were unmeasurable (Fig. 3). Category 4 was observed only in people over 70 years of age.

We analyzed the remaining 577 items for interobserver ICC values of the PMI in terms of patient age and observer specificity. The two ICC values of a graduating student for the age group of 50-59 years were 0.399 and 0.395; this indicated poor reliability (Table 1). Moreover, the intraobserver reproducibility was 0.611-0.752, and 7 values fell in the fair to good range, while only 1 value was excellent (Table 2).

Table 3. Intraobserver intraclass correlation coefficient (ICC) values of the mandibular cortical width (MCW), the distance from the superior margin (SL) and inferior margin (IL) of the mandibular inferior border

	MCW	SL	IL
Observer 1	0.773	0.753	0.725
Observer 2	0.779	0.673	0.649
Observer 3	0.696	0.657	0.626
Observer 4	0.731	0.657	0.640
Average	0.745	0.685	0.660

Table 4. Results of the Pearson correlation test

Gender	Number	MCW		SL		IL	
Male	294	r	0.111	r	0.019	r	0.038
		P	.057	*P*	.751	*P*	.517
Female	297	r	−0.234*	r	0.015	r	0.031
		P	.000*	*P*	.801	*P*	.595

MCW: mandibular cortical width, SL: distance between the superior margin of the mental foramen and inferior border of the mandible, IL: distance between the inferior margin of the mental foramen and the inferior border of the mandible, *:$P<0.05$.

A high interobserver value is meaningful only when the intraobserver value is also high. To identify the factors that negatively influenced reliability, we analyzed the ICC values of the MCW, SL, and IL measurements (Table 3). The intraobserver ICC values of MCW, SL, and IL were 0.745 (0.696-0.779), 0.685 (0.657-0.753), and 0.660 (0.626-0.725), respectively.

Further, the data obtained in the first trial by observer 1, the most experienced observer, were analyzed using the Pearson correlation test. A statistically significant negative correlation was observed between MCW and patient age; that is, the width decreased with an increase in patient age. No statistically significant association was observed for SL or IL (Table 4).

Discussion

In this study, to assess the usefulness of PMI as an index to screen for osteoporosis, both the distance to the mental foramen and the MCW were measured separately. Measurability of the mental foramen showed both interobserver and intraobserver variability. In cases of reconstruction after lesion removal, the distances to both the mandibular cortex and the mental foramen were unmeasurable; here, we believe that the proportion of patients who underwent reconstruction surgery was high considering the characteristics of referral hospitals. In some cases, the mental

foramen could not be detected clearly because of cysts or inflammation. Moreover, in cases where the alveolar bone was resorbed to the level of the mental foramen, the exact location of the mental foramen, particularly the upper edge, could not be detected. Older patients are more likely to have osteoporosis, and if the measurement cannot be made because of alveolar bone resorption, the use of the PMI as a screening index could be problematic. We also observed the possibility of variations in measurements depending on the shape of the mental foramen; in particular, it was difficult to pinpoint the position of the inferior margin when anterior loops were observed. In some cases, we also found it difficult to determine the boundaries when an implant was seen to overlap with the mental foramen. In the additional analyses excluding the 23 unmeasurable data items, the intraobserver ICC of MCW was higher than that of the SL and IL measurements, indicating that the margin determination of the mental foramen may have a greater influence on the reliability of the PMI than the MCW. Moreover, the fact that the measurements of graduating dental students had markedly lower reliability than those of the radiology residents shows that the experience of the observer also played a role in determining the quality of the results. These results correspond with the results of an earlier study that reported extensive variation among general dental practitioners' measurements of the GI, AI, MCW, and MCI.[5] Therefore, although the reliability of the PMI value is compromised when non-specialists perform osteoporosis screening using the PMI at local dental clinics, the ability to determine the margin of the mental foramen may be a critical factor in the generation of the PMI value. However, Nakamoto et al.[12] demonstrated that untrained general dental practitioners could use MCW and the MCI as a tool for a further screening for osteoporosis.

Meanwhile, as shown in the correlation test, aging was significantly associated with a reduced MCW in female patients. SL or IL did not show any significant age-related differences. Similarly, according to a previous study by White et al.,[13] distances from the mental foramen to the inferior border of the mandible exhibited no statistically significant correlation among normal, osteopenia, and osteoporosis patient groups diagnosed on the basis of femur bone mineral density. Moreover, our result showed no statistically significant age-related difference in the MCW in male patients. Previous studies likewise showed MCW to be a more useful screening factor for bone mineral density in females than in males.[14,15] According to another study using a global active shape model on 6096 images, the decrease in MCW accelerated after 42.5 years of age in females, while there is a slow but steady decrease in MCW in males after 36 years of age.[16] Therefore, a large-scale study should be conducted to analyze the data of male subjects.

During the measurement of the MCW, in some cases, the borders appeared unclear because of sclerotic changes. Moreover, in cases where the borders were masked by anatomical structures such as the hyoid bone or cervical vertebrae, or in cases of increased anterior cortical thickness due to imaging angulation or the jaw shape, the reliability of measurement values decreased significantly. Lastly, the cortical bone in older patients appeared as if it were being peeled off, and the measurement values differed according to the identified upper edge of the cortical bone.

Hastar et al.[17] reported that MCW, the MCI, and the PMI exhibited statistically significant differences between patients with and without osteoporosis. However, Klemetti et al.[8] suggested that the correlation between bone mineral density and the PMI was weak. Moreover, Alkult et al.[18] mentioned that 37.5% of the images (12 of 32) could not be evaluated because of insufficient identification of the mental foramen or cortical width.

In conclusion, this study focused on measurability and there were limitations in measuring both the mental foramen and the MCW. However, the PMI including the distance to the mental foramen had more drawbacks than MCW with respect to osteoporosis screening. In other words, MCW had fewer limitations for making measurements than were encountered with the mental foramen, and the thickness and shape of the cortical bone changed with the age of the patients. This result is in agreement with the findings of previous studies.[8,18,19] However, to obtain meaningful and objective results, we need to develop a measurement method that limits the likelihood of errors associated with manual measurements, and several studies have been conducted for developing such a methodology using a computer-aided system.[16,20-22] Therefore, further studies are required to examine MCW in various large populations using a computer-based program.

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