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Three panoramic indices for identification of healthy older people at a high risk of osteoporosis

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Abstract *Background:* This study aimed to identify whether healthy older adults are at a high risk of osteoporosis based on the association between the T-score values of bone mineral density (BMD) and three panoramic indices.

Materials and methods: All participants (50–64 years old) underwent calcaneal quantitative ultrasound (QUS) bone densitometry. In total, 371 panoramic images were included in the analysis. The mandibular cortical width (MCW), mandibular cortical index (MCI), and panoramic mandibular index (PMI) were the three parameters assessed. The data were examined using one-way analysis of variance or Kruskal–Wallis H and post hoc tests. Spearman's rho was used to measure correlation coefficients.

Results: T-score distributions in the normal, osteopenia, and osteoporosis categories were 80 (21.6%), 236 (63.6%), and 55 (14.8%), respectively. T-scores were significantly related to age, MCW, PMI, and MCI ($p < 0.001$). Participants with osteopenia and a risk of progression to osteoporosis had an average MCW value of < 3.38 mm, a PMI of < 0.31, and an MCI class 2 and 3 distribution in 211 (56.9%) participants. The highest to lowest correlation coefficients with a significant relationship to the T-score were for age ($r = -0.844$), MCI ($r = 0.456$), MCW ($r = 0.359$), sex ($r = 0.354$), and PMI value ($r = 0.292$).

Conclusions: This study found that healthy older people with Class 3 MCI, an MCW < 3 mm, and a PMI ratio < 0.3 had a significant association with lower BMD T-scores on QUS and were at higher risk of osteoporosis.

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1. Introduction

Panoramic radiography is used extensively in dentistry. The detection of osteoporosis based on panoramic radiography has become an interesting topic of study owing to the global burden of the disease. Osteoporosis can complicate dental and oral care, exacerbate clinical attachment loss, and cause excessive bone resorption, eventually resulting in tooth loss

(Straka et al., 2015). It is difficult to detect osteoporosis, which complicates its prevention. The three most frequently used detection methods for panoramic radiography are the mandibular cortical width/mental index (MCW/MI), the panoramic mandibular index (PMI), and the mandibular cortical index (MCI), also known as the Klemetti index (Ledgerton et al., 1999; Devlin and Horner, 2002; Taguchi, 2010; Mansour et al., 2013).

The MCI, designed by Klemetti et al. (1994), enables the rapid interpretation of the risk of osteoporosis. It can be efficiently used in dental practice; however, difficulties in determining cortical bone height or distinguishing between the cortical and spongiosa bones in the jaw are influenced by observer experience (Klemetti et al., 1994; Taguchi et al., 2010). MCW measurements, introduced by Taguchi et al. (1996), are associated with the determination of mental foramen position. Studies have found a positive relationship between MCW and the lumbar spine (Devlin et al., 2002; Taguchi et al., 1996). The PMI introduced by Benson et al. (1991) has cutoff values related to the following two measurement points: the mental foramen and inferior border of the mandible. A significant association has been reported between low PMI values and osteoporosis progression (Klemetti et al., 1993). Thus, these methods are useful for early detection of osteoporosis.

The cut-off values for healthy participants and those with osteopenia and osteoporosis based on MCI, MCW, and PMI have been investigated. A quantitative ultrasound (QUS) bone densitometry study found that women with class 3 MIC radiographs had a high risk of osteoporosis (Kiswanjaya et al., 2010, 2014). Using the MCW method, a value of ≤ 3 to ≤ 4.5 mm is indicative of osteoporosis (White et al., 2005; Devlin et al., 2007). A possible explanation for this relatively wide measurement range is the lack of adjustment for panoramic magnification resulting from the different types of digital panoramic machines. Although the PMI values can range from 0.27 to 0.38, many researchers use a value of < 0.3 for the determination of osteopenia (Ledgerton et al., 1999; Benson et al., 1991). Drozdzowska et al. (2002) and Grocholewicz et al. (2018) did not find a significant association between PMI and bone mineral density (BMD) using QUS. They further showed that PMI can be used as a marker of low BMD only when the average PMI in the population is known. The small number of participants may have been an important limiting factor of this study (Drozdzowska et al., 2002). Kanya et al. (2017) showed no association between MCW and age and indicated that further research should be conducted with more number of participants and taking into consideration the observer's radiographic interpretation skills (Kanya et al., 2017). Therefore, this study aimed to identify individuals at a high risk of osteoporosis based on the association between each of the three previously discussed parameters (i.e., MIC, MCW, and PMI) and the T-score values for BMD using a non-radiation tool (QUS) in healthy older people.

2. Material and methods

This study was conducted between June 2019 and December 2019. The research protocol was approved by the Universitas Indonesia Faculty of Dentistry Research Ethics Commission (Letter No. 35, Ethical Approval: FKGUI/III/2019), and informed consent was obtained from all participants.

This study included 380 healthy participants from Depok and West Bekasi, two regions of West Java Province, Indonesia. The inclusion criteria were as follows: age 50–64 years, no history of fractures, not receiving any osteoporosis medication, and able to undergo QUS and panoramic radiography. According to the International Society for Clinical Densitometry, bone densitometry dual-energy X-ray absorptiometry (DXA) is an accurate diagnostic tool for osteoporosis that is used only for women > 64 years and men > 69 years (Shuhart et al., 2019). However, osteoporosis-related fractures can occur in younger patients. Therefore, the age range 50–64 was chosen to investigate the possibility of osteoporosis in healthy older people using panoramic radiography, which is used more frequently and is less expensive than DXA. Nine radiographs were excluded as they did not meet the criteria for head positioning on the panoramic radiographs; the issue being that the head was tilted too far up or down. All participants were examined in the standard panoramic position. Radiographers at a dental hospital performed the panoramic radiography. In all, 371 panoramic images were included in the analysis.

2.1. Bone densitometry

The bone density was measured using QUS densitometry. All participants underwent calcaneal QUS using a Lunar Achilles Insight bone densitometer (GE Healthcare, Milwaukee, WI, USA). The patients were categorized as normal (T-score > -1.0), osteopenia (T-score $= -1$ to -2.5), or osteoporosis (T-score < -2.5) based on the World Health Organization (WHO) criteria.

2.2. Measurement of mandibular cortical index, mandibular cortical width, and panoramic mandibular index values from panoramic images

Digital panoramic radiographs were obtained using Veraviewepocs 2D® (J. Morita Corp., Kyoto, Japan). Exposure was performed at 10 mA-seconds (mAs) for 12–15 s at 70–80 kVp. The digital data sampling process was completed using i-Dixel imaging software (J. Morita Corp., Kyoto, Japan). MCI, MCW, and PMI values were obtained by two observers who used the same laptop. Before measurements were taken, the machines were calibrated, image magnification was set to 1×, brightness and contrast of the radiographs were optimally adjusted, and screen brightness on the laptop was set to the maximum. This type of panoramic unit has a magnification factor of 1.3; therefore, the MCW and PMI measurements were calibrated by 1.3. Both observers were experts in oral radiology with > 10 years of experience. Interpretation of the MIC, MCW, and PMI values was limited to 5–8 panoramic radiographs per day to avoid fatigue and errors in the analysis. Fifty panoramic radiographs were randomly selected from the total number of samples. Intra-and inter-observer agreements for the MCI and MCW data were determined using the kappa coefficient and Bland–Altman test, respectively.

MCI was measured using the Klemetti index introduced in 1994. Based on the condition of the inferior mandibular cortex, MCI was divided into three classes: Class 1, indicative of a normal cortex, showing that the mandibular cortical bone

appears as a radiopaque band with no radiolucency or porosity on both sides; Class 2, indicative of a mildly or moderately eroded cortex, showing the formation of endosteal cortical residues on one or both sides; Class 3, indicative of a severely eroded cortex, clearly showing porous cortical residues on one or both sides. The mean MCW was determined from the panoramic images, as described by Taguchi et al. (1996). For the PMI ratio, the description by Benson et al. (1991) was used (Fig. 1).

2.3. Statistical analysis

Data were analyzed using SPSS (version 17.0; SPSS Inc. Chicago, IL, USA). Normally distributed data were analyzed using one-way analysis of variance, whereas for categorical data chi-square and linear-by-linear association tests were employed. Correlation coefficients were measured using Spearman's rho. To differentiate the participants with osteopenia and osteoporosis from healthy participants, age and T-scores for MCI, MCW, and PMI were used as categorical variables. Statistical significance was set at $p < 0.05$.

3. Results

The Kappa coefficient between intra-and inter-observer agreement for MCI was 0.88 and 0.847, respectively. The mean difference and standard deviation of the Bland–Altman test between intra-and inter-observer agreement for MCW were 0.02 ± 0.09 and 0.03 ± 0.29, respectively. The upper and lower limits of the intra-observer agreement of the Bland–Altman test were 0.1137 and −0.0812, respectively, while the inter-observer agreement was 0.3198 and −0.2542, respectively. There was no significant difference between the measurements of the intra-and inter-observer agreement following the Bland–Altman test ($p > 0.05$, one-sample t-test). As the measurements were considered to be in agreement, they were used interchangeably.

Measurements were performed using radiographs of 371 participants that included 182 men (49.1%) and 189 women (50.95%). In general, the T-scores and MCW, PMI, and MIC values were lower in women than in men. In this study,

the MCI values indicated that male participants with an average age of 54 years were most frequently in Class 1, and female participants with an average age of 57 years were most frequently in Class 2 (Table 1).

To analyze the relationship between age and the measured variables, the participants were divided into three 5-year age groups (Table 2). The distribution was as follows: category I (50–54 years), 39.6% (n = 147); category II (55–59 years), 35.6% (n = 132); and category III (60–64 years), 24.8% (n = 92). The T-scores and MCW, PMI, and MCI values of the category III participants were significantly lower than those of the category I and II participants. Based on the cutoff values, which are a mean MCW of < 3 mm and PMI ratio of < 0.3, the values for the participants in the 60–64 years age group were indicative of a high risk of osteoporosis.

Table 3 shows the T-scores, which were categorized according to the WHO guidelines. The T-score distribution was as follows: normal, 80 (21.6%); osteopenia, 236 (63.6%); osteoporosis, 55 (14.8%). In each category, T-scores were significantly related to age, MCW, and PMI. Participants in the osteopenia and osteoporosis categories had average MCW values of $< 3.38 \pm 0.5$ mm and PMI ratio values of < 0.31. The participants with an average age of 62 years were in the osteoporosis category. There was a significant relationship between the MIC classification and T-score. The MCI distributions for Classes 1, 2, and 3 were 160 (43.1%), 173 (46.7%), and 38 (10.2%), respectively. Patients with Class 3 MIC classification were in the osteoporosis category.

Table 4 shows the results of Spearman's rho, and indicates significant correlations among all variables. The highest to lowest correlation values related to the T-score were for age, MCI, MCW, PMI values, and sex.

4. Discussion

T-scores were significantly correlated with MCI ($r = -0.456$), MCW ($r = 0.359$), and PMI ($r = 0.292$) values. There was a significant relationship between the three values. Among these, MCI had the highest correlation coefficient with T-score. The MCI can be interpreted more quickly (approximately 5–10 s) than the other two values. Moreover, as per the results of this
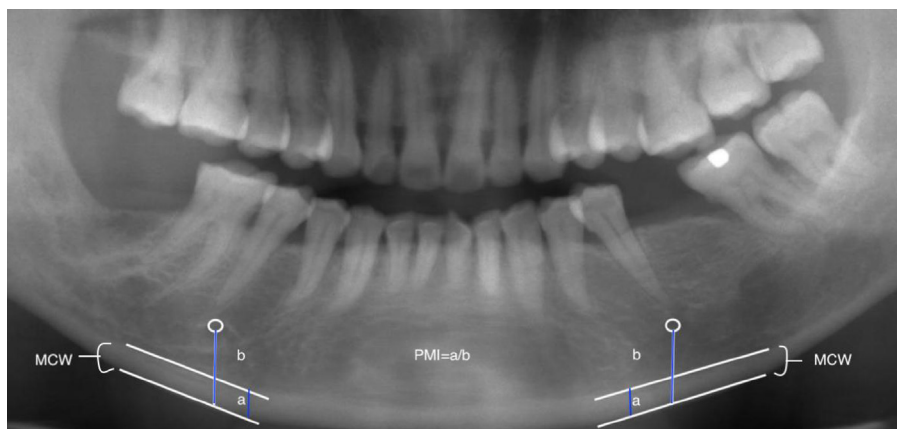
Fig. 1 The mandibular cortical width (MCW) indicates the mandibular cortical width between the inferior and superior lines. The panoramic mandibular index (PMI) ratio was calculated as the ratio of measurement of (a) the cortical thickness and (b) the point from the inferior border of the mental foramen to the inferior border of the mandible.

Table 1 Sex-wise distribution of parameters amongst the study participants.

	Men	Women	*p*-value
Age (years)	54.82 ± 3.75*	57.56 ± 3.88*	< 0.001,
	54 (50–64)**	57 (50–64)**	chi-square test
T-score	−1.33 ± 1.05*	−1.97 ± 0.71*	< 0.001,
	−1.46 (-4.14–1.73)**	−2.05 (-3.99–1.02)**	independent *t*-test
MCW (mm)	3.4 ± 0.54*	3.28 ± 0.59*	< 0.05,
	3.48 (1.48–4.44)**	3.32 (1.85–4.76)**	independent *t*-test
PMI	0.32 ± 0.05*	0.31 ± 0.06*	Not significant
	0.31 (0.13–0.43)**	0.31 (0.15–0.56)**	
MCI Class 1	128 (70.3%)	32 (16.9%)	< 0.001,
Class 2	46 (25.3%)	127 (67.2%)	chi-square test
Class 3	8 (4.4%)	30 (15.9%)	
Total	182 (100%)	189 (100%)	

* Mean ± SD.
** Median (max–min) MCW, mandibular cortical width; PMI, panoramic mandibular index; MCI, mandibular cortical index.

Table 2 Relationship between age and T-score, mandibular cortical width (MCW), panoramic mandibular index (PMI), and mandibular cortical index (MCI).

	Age Categories			*p*-value
	I (50–54 years)	**II (55–59 years)**	**III (60–64 years)**	
T-Score*	−0.9 ± 0.8	−1.82 ± 0.49	−2.63 ± 0.41	*p* < 0.001, one-way ANOVA
MCW (mm)*	3.58 ± 0.41	3.34 ± 0.48	2.93 ± 0.66	*p* < 0.001, one- way ANOVA
PMI**	0.33 (0.16–0.43)	0.31 (0.2–0.47)	0.28 (0.14–0.56)	*p* < 0.001, Kruskal–Wallis test
MCI Class 1	93 (63.3%)	50 (37.9%)	17 (18.5%)	*p* < 0.001, chi-square tests,
Class 2	52 (35.4%)	72 (54.5%)	49 (53.3%)	linear-by-linear association test
Class 3	2 (1.4%)	10 (7.6%)	26 (28.3%)	

* Mean ± SD.
** Median (max–min).

Table 3 Relationship between T-score (according to the World Health Organization classification) and age, mandibular cortical width (MCW), panoramic mandibular index (PMI), and mandibular cortical index (MCI).

	T-Score			*p*-value
	Normal (≥-1)	**Osteopenia (-1 to −2.5)**	**Osteoporosis (≤-2.5)**	
Age (years)*	52.19 ± 1.84	56.20 ± 3.18	62.15 ± 1.95	*p* < 0.001, one-way ANOVA
MCW(mm)*	3.53 ± 0.41	3.38 ± 0.5	2.85 ± 0.73	*p* < 0.001, one- way ANOVA
PMI**	0.33 (0.16–0.47)	0.31 (0.15–0.47)	0.28 (0.14–0.56)	*p* < 0.001, Kruskal–Wallis test
	MCI			*p*-value
	Class 1	**Class 2**	**Class 3**	
T-Score*	−1.2 ± 0.9	−1.84 ± 0.72	−2.61 ± 0.6	*p* < 0.001, one-way ANOVA

* Mean ± SD.
** Median (max–min).

study, the correlation coefficient generated by MCI was greater than those generated by PMI and MCW. These findings are similar to those of Grocholewicz et al. (2018), who emphasized the poor utility of PMI and MCW in identifying the risk of osteoporosis in postmenopausal women (Grocholewicz et al., 2018). Another study by Munhoz et al. (2020) also demonstrated an inverse correlation between MCI and proximal forearm DXA in 44 men. They concluded that MCI is a useful screening tool for low BMD (Grocholewicz et al., 2018; Munhoz et al., 2020). However, the results are greatly influenced by the observer experience. General dental practitioners with more experience or oral radiographic interpretation train-ing (approximately 2 years) will still obtain lower sensitivity and specificity values than oral radiologists (Lee et al., 2005). Under ideal interpretation conditions in general dental prac-tices with sufficient time to measure panoramic images, the MCW as described by Taguchi et al. (1996) should be used to avoid misinterpretation of MCI results. The anatomical landmarks of the mental foramen and the superior or inferior parts of the mandibular cortex are more accurate than the visual interpretation. A *meta*-analysis found variations in the sensitivity of these three values; however, the specificity of MCW was higher than those of the other two values (Calciolari et al., 2015).

Table 4 Spearman's rho correlation coefficient values for T-score, mandibular cortical width (MCW), panoramic mandibular index (PMI), and mandibular cortical index (MCI), age, and sex.

			MCW	PMI	MCI	Age	Sex
Spearman's rho	T-Score	Correlation coefficient	0.359[**]	0.292[**]	−0.456[**]	−0.844[**]	−0.354[**]
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	MCW	Correlation coefficient	—	0.831[**]	−0.165[**]	−0.377[**]	−0.118[*]
		p-value	—	< 0.001	< 0.005	< 0.001	< 0.05
	PMI	Correlation coefficient	—	—	−0.104[*]	−0.319[**]	−0.059
		p-value	—	—	< 0.05	< 0.001	Not significant
	MCI	Correlation coefficient	—	—	—	0.401[**]	0.522[**]
		p-value	—	—	—	< 0.001	< 0.001
	Age	Correlation coefficient	—	—	—	—	0.341[**]
		p-value	—	—	—	—	< 0.001

[**] Correlation is significant at the 0.01 level (two-tailed).
[*] Correlation is significant at the 0.05 level (two-tailed).

The present study was not designed to assess the diagnostic value of these three values. Furthermore, the low r values imply that a maximum of 25% of the variability in the T-score is explained by the panoramic radiograph indices. However, systematic reviews have shown the benefits of these three diagnostic values for detecting the risk of osteoporosis (Calciolari et al., 2015; Taguchi et al., 2010). The combined application of these three values is an optimal approach for determining the risk of osteoporosis. Therefore, in general dental practice, their continued use is recommended as a potent marker of osteoporosis.

This study found a significant relationship between T-scores and MCI, MCW, and PMI values (Table 3). The mean T-score (≤-2.5) of Class 3 MCI participants (10.2%) was in the osteoporosis category. In comparison, participants with a T-score in the osteoporosis category (14.8%) had a mean MCW value of 2.85 mm and a PMI ratio of 0.28. These results are consistent with those of previous studies that concluded that participants with Class 3 MCI, an MCW cutoff of < 3 mm, and a PMI ratio of < 0.3 were at high risk of osteoporosis (Taguchi et al., 2014; Benson et al., 1991; Drozdzowska et al., 2002). In the present study, Spearman's rho indicated a significant relationship between the three panoramic values. Therefore, it is recommended that these ranges or cutoff values be used in general dental practice, and that patients be informed if these values are identified on panoramic confirm a definite diagnosis and to undergo appropriate treatment for osteoporosis before receiving dental and oral care. This should be performed in patients with osteoporosis suspected to have complications in dental and oral care.

A significant relationship was found between age and T-scores (Table 2). Participants aged 60–64 years (mean age: 62 years) met the T-score criteria for osteoporosis. The mean MCW was 2.93 mm, and the PMI ratio was 0.28. In a 5-year study of 1,177 patients, 90 (7.6%) patients aged < 65 years experienced hip fractures (Pillai et al., 2011). Though, the percentage of patients with fractures was < 10%, these findings revealed that fracture-related osteoporosis can be experienced by patients aged < 65 years. These results support the recommendations of this study. The three panoramic values should be used for the early detection of osteoporosis, especially for patients aged < 65 years. This can help medical and dental professionals prevent the development of osteoporosis.

5. Conclusion

This study found that among healthy older people, those with Class 3 MCI, an MCW < 3 mm, and a PMI ratio < 0.3 were significantly associated with lower BMD T-scores on QUS and considered to be at higher risk of osteoporosis.

Ethical statements

The authors declare that the work were carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

The research protocol and informed consent were approved by the Universitas Indonesia Faculty of Dentistry Research Ethics Commission (Letter No. 35, Ethical Approval: FKGUI/III/2019).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2022.05.006.

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