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Original Article

Quantitative analysis of mandibular cortical morphology using artificial intelligence-based computer assisted diagnosis for panoramic radiography on underlying diseases and dental status in women over 20 years of age

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Abstract *Background/purpose:* Recently, an artificial intelligence-based computer-assisted diagnosis (AI-CAD) for panoramic radiography was developed to scan the inferior margin of the mandible and automatically evaluate mandibular cortical morphology. The aim of this study was to analyze quantitatively the mandibular cortical morphology using the AI-CAD, especially focusing on underlying diseases and dental status in women over 20 years of age.
Materials and methods: 419 patients in women over 20 years of age who underwent panoramic radiography were included in this study. The mandibular cortical morphology was analyzed with an AI-CAD that evaluated the degree of deformation of the mandibular inferior cortex (MIC) and mandibular cortical index (MCI) automatically. Those were analyzed in relation to underlying diseases, such as diabetes, hypertension, dyslipidemia, rheumatism and osteoporosis, and dental status, such as the number of teeth present in the maxilla and mandible.
Results: The degree of deformation of MIC in women under 51 years of age (21–50 years; n = 229, 16.0 ± 12.7) was significantly lower than those of over 50 years of age (51–90 years; n = 190, 45.1 ± 23.0), and the MCI was a significant difference for the different age group. Regarding the degree of deformation of MIC and MCI in women over 50 years of age,

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osteoporosis and number of total teeth present in the maxilla and mandible were significant differences.
Conclusion: The results of this study indicated that the mandibular cortical morphology using the AI-CAD is significantly related to osteoporosis and dental status in women over 50 years of age.

Introduction

The mandibular cortical index (MCI) is a qualitative index that assesses the appearance of the mandibular endosteum.[1] It classifies the mandibular cortex as Class 1, where the mandibular cortical bone has a normal shape, indicating that the patient is not at risk; Class 2, where the mandibular cortical bone presents few radiolucent areas with semi-circular or linear shape; and Class 3, where the mandibular cortical bone presents several radiolucent areas, indicating that the patient is at high risk of systemic osteoporosis. The MCI is useful as an auxiliary tool for identifying postmenopausal females at risk of low bone mineral density (BMD), as it correlates with skeletal BMD measured by dual X-ray absorptiometry (DXA).[2]

The computer-assisted diagnosis (CAD) systems that may help differential diagnosis by using medical images take place in the literature day by day along with the recent development of artificial intelligence (AI) methods and computer hardware.[3] There are studies on the prediction and clarification of osteoporosis with machine learning and fuzzy systems by obtaining features from panoramic images in the literature.[4,5] Recently, an AI-CAD system for panoramic radiography "PanoSCOPE" was developed to scan the inferior margin of the mandible and automatically evaluate mandibular cortical morphology, such as the MCI, and the AI-CAD system is an effective tool for pre-screening of osteoporosis by panoramic radiography.[6,7] The AI-CAD system has been reported on the mandibular cortical morphology in medication-related osteonecrosis of the jaw with osteoporosis, in relation to age and gender, and pre- and post-dental implant operations.[8–10] However, no studies were found for mandibular cortical morphology in relation to underlying diseases and dental status using the AI-CAD by PubMed. We analyzed quantitatively mandibular cortical morphology using the AI-CAD for panoramic radiography, especially focusing on underlying diseases and dental status in women over 20 years of age.

Materials and methods

Patients

This prospective study was approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-R-318), and all patients gave written informed consent. 419 patients in women over 20 years of age (mean age, 49.3 years; range, 21–90 years) who underwent panoramic radiography at our university hospital from April 2022 to September 2022 were included in this study. The patients with dental implants and jaw lesions, such as cysts and tumors, were excluded. The underlying diseases, such as diabetes, hypertension, dyslipidemia, rheumatism and osteoporosis, was recorded from the electronic medical chart of the university hospital.

Panoramic imaging and data analysis

Panoramic radiography was performed with panoramic X-ray unit (Veraviewepocs; MORITA, Kyoto, Japan), following our hospital maxillofacial protocol.[8–10] Regarding dental status, the numbers of total anterior and posterior teeth present were assessed from the panoramic radiography.[11,12] Anterior teeth were defined as central and lateral incisors and canines, and posterior teeth as premolars and molars.[13] Third molars were excluded. Root remnants were counted as teeth except for the ones which were totally embedded in bone.[14]

The mandibular cortical morphology on panoramic radiographs was analyzed with an AI-CAD (PanoSCOPE; MEDIA, Tokyo, Japan) that evaluated the degree of deformation of the mandibular inferior cortex (MIC) and the MCI automatically, following our hospital maxillofacial protocol.[8–10] The degree of deformation of MIC was calculated using the thickness and roughness of the mandibular cortex with AI-CAD. The MCI classification was as follows: normal (Class 1, Fig. 1), mildly to moderately eroded (Class 2, Fig. 2), or severely eroded (Class 3, Fig. 3) with AI-CAD.

Statistical analysis

The degree of deformation of MIC at different ages was performed by one-way measures analysis of variance with Tukey's honestly significant difference test and Mann–Whitney U-test. The degree of deformation of MIC in relation to underlying diseases and dental status was performed by Mann–Whitney U-test. MCI classifications of all patients were performed by Pearson chi-square test. Those statistical analyses were evaluated with the statistical package SPSS Statistics (version 26, IBM Japan, Tokyo, Japan) using a 5% significance level.

Results

The degree of deformation of MIC using AI-CAD at different ages in women over 20 years of age was shown in Table 1. The degree of deformation of MIC in over 20-years group (21–30 years, 15.1 $\pm$ 13.2) was lower than those in over 50-

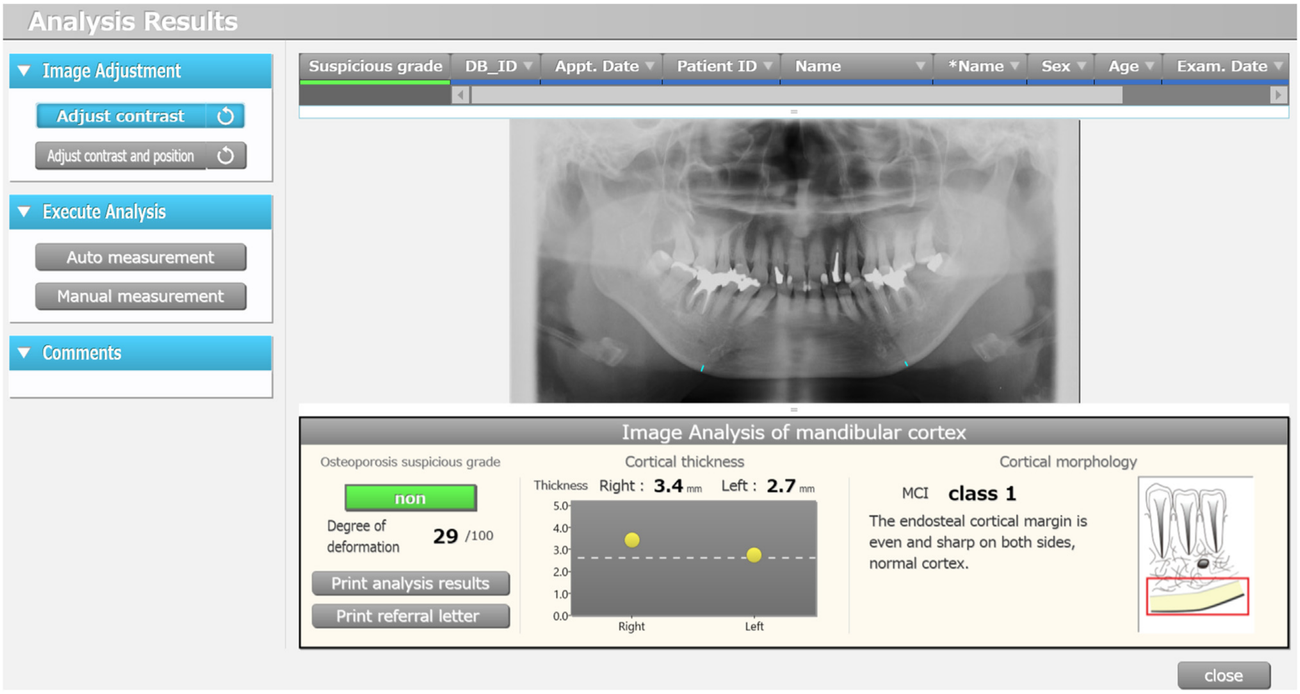

Figure 1 PanoSCOPE software in a 73-year-old woman indicates that the degree of deformation and MCI are 29/100 and Class 1, respectively.

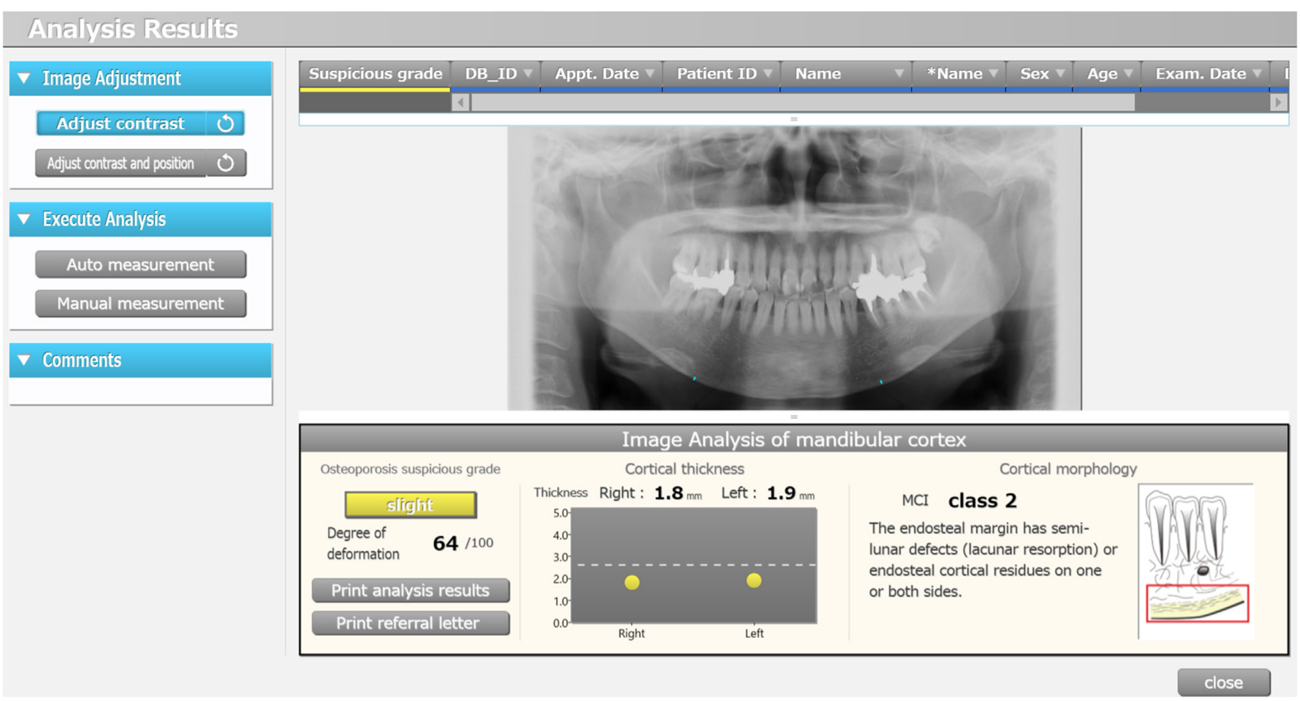

Figure 2 PanoSCOPE software in a 62-year-old woman indicates that the degree of deformation and MCI are 64/100 and Class 2, respectively.

years group (51—60 years, 31.7 ± 22.5, $P < 0.001$), over 60-years group (61—70 years, 48.1 ± 21.7, $P < 0.001$), over 70-years group (71—80 years, 48.9 ± 19.4, $P < 0.001$) and over 80-years group (81—90 years, 60.1 ± 19.5, $P < 0.001$), although those in over 20-years group was not a significant difference in over 30-years group (31—40 years, 15.8 ± 11.9, $P = 1.000$) and over 40-years group (41—50 years, 17.9 ± 12.7, $P = 0.951$). Furthermore, the degree of deformation of MIC in women over 20 years of age (21—50 years; n = 229, 16.0 ± 12.7) was significantly lower than those of over 50 years of age (51—90 years; n = 190, 45.1 ± 23.0, $P < 0.001$).

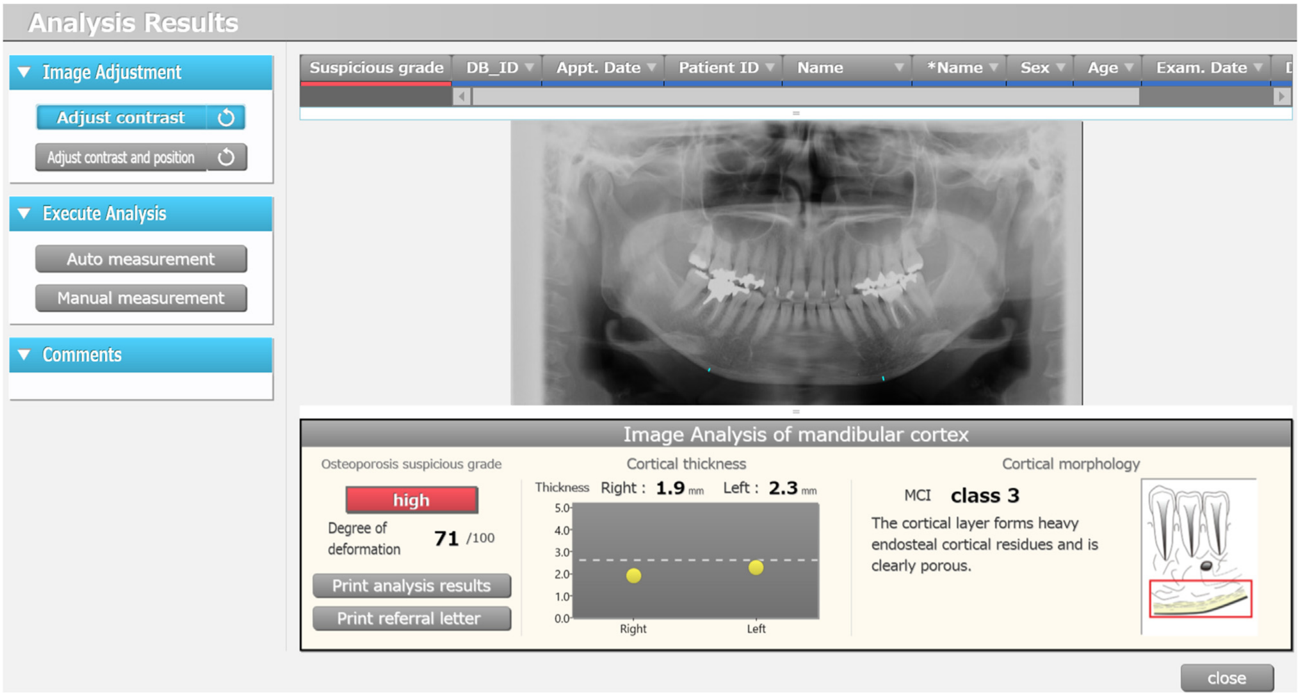

Figure 3 PanoSCOPE software in a 56-year-old woman indicates that the degree of deformation and MCI are 71/100 and Class 3, respectively.

The mandibular cortical index (MCI) using AI-CAD at different ages in women under 51 and over 50 years of age was shown in Table 2. The MCI was a significant difference for the different age groups ($P < 0.001$). Furthermore, the MCI under 51 years of age was not significant difference for different age groups ($P = 0.967$), and the MCI over 50 years of age was a significant difference for different age groups ($P < 0.001$).

The degree of deformation of MIC using AI-CAD in relation to underlying diseases in women under 51 and over 50 years of age was shown in Table 3. Regarding those in relation to underlying diseases in women over 50 years of age, osteoporosis was a significant difference ($P = 0.006$). Furthermore, the MCI using AI-CAD in relation to underlying diseases in women under 51 and over 50 years of age was shown in Table 4. Regarding those in relation to underlying diseases in women over 50 years of age, osteoporosis was a significant difference ($P = 0.013$).

The degree of deformation of MIC using AI-CAD in relation to dental status in women under 51 and over 50 years of age was shown in Table 5. Regarding those in relation to

Table 1 Degree of deformation of mandibular inferior cortex using artificial intelligence-based computer-assisted diagnosis at different ages in women over 20 years of age.

Age (years)	Cases	Degree of deformation of MIC using AI-CAD		
		Mean ± SD	Range	*P*-value
21–30	100	15.1 ± 13.2	0–66	–
31–40	72	15.8 ± 11.9	1–71	1.000
41–50	57	17.9 ± 12.7	0–65	0.951
51–60	58	31.7 ± 22.5	1–78	<0.001
61–70	50	48.1 ± 21.7	6–86	<0.001
71–80	54	48.9 ± 19.4	6–90	<0.001
81–90	28	60.1 ± 19.5	16–91	<0.001

Abbreviations: MIC, mandibular inferior cortex; AI-CAD, artificial intelligence-based computer-assisted diagnosis; SD, standard deviation.
Under 51 years of age (21–50 years; n = 229, 16.0 ± 12.7) vs. over 50 years of age (51–90 years; n = 190, 45.1 ± 23.0, $P < 0.001$).

Table 2 Mandibular cortical index using artificial intelligence-based computer-assisted diagnosis at different ages in women under 51 and over 50 years of age.

Age (years)	Cases	Mandibular cortical index using AI-CAD			
		Class 1 (%)	Class 2 (%)	Class 3 (%)	*P*-value
Under 51 years of age	229	212 (92.6%)	14 (6.1%)	3 (1.3%)	0.967
21–30	100	94 (94.0%)	5 (5.0%)	1 (1.0%)	
31–40	72	66 (91.7%)	5 (6.9%)	1 (1.4%)	
41–50	57	52 (91.2%)	4 (7.0%)	1 (1.8%)	
Over 50 years of age	190	68 (35.8%)	79 (41.6%)	43 (22.6%)	<0.001
51–60	58	38 (65.5%)	14 (24.1%)	6 (10.3%)	
61–70	50	17 (34.0%)	20 (40.0%)	13 (26.0%)	
71–80	54	11 (20.4%)	32 (59.3%)	11 (20.4%)	
81–90	28	2 (7.1%)	13 (46.4%)	13 (46.4%)	

Abbreviations: AI-CAD, artificial intelligence-based computer-assisted diagnosis.
Under 51 years of age vs. over 50 years of age ($P < 0.001$).

Table 3 Degree of deformation of mandibular inferior cortex using artificial intelligence-based computer-assisted diagnosis in relation to underlying diseases in women under 51 and over 50 years of age.

Underlying diseases	Degree of deformation of mandibular inferior cortex using AI-CAD							
	Under 51 years of age (21—50 years, n = 229)				Over 50 years of age (51—90 years, n = 190)			
	Cases	Mean ± SD	Range	*P*-value	Cases	Mean ± SD	Range	*P*-value
Diabetes				—				0.092
Presence	0				10	56.5 ± 13.6	33—81	
Absence	229	16.0 ± 12.7	0—71		180	44.5 ± 23.3	1—91	
Hypertension				0.541				0.691
Presence	1	8	8		60	44.5 ± 20.5	5—89	
Absence	228	16.1 ± 12.7	0—71		130	45.4 ± 24.2	1—91	
Dyslipidemia				0.122				0.643
Presence	1	39	39		34	46.3 ± 23.7	5—85	
Absence	228	15.9 ± 12.6	0—71		156	44.9 ± 22.9	1—91	
Rheumatism				0.048				0.648
Presence	2	38.5 ± 17.7	26—51		6	48.3 ± 18.9	11—62	
Absence	227	15.8 ± 12.5	0—71		184	45.0 ± 23.2	1—91	
Osteoporosis				—				0.006
Presence	0				35	54.6 ± 18.4	17—89	
Absence	229	16.0 ± 12.7	0—71		155	43.0 ± 23.5	1—91	

Abbreviations: AI-CAD, artificial intelligence-based computer-assisted diagnosis; SD, standard deviation.

dental status in women over 50 years of age, the number of total teeth present in the maxilla and mandible was a significant difference ($P < 0.001$ and $P < 0.001$, respectively). Furthermore, the MCI using AI-CAD in relation to dental status in women under 51 and over 50 years of age was shown in Table 6. Regarding those in relation to dental status in women over 50 years of age, the number of total teeth present in the maxilla and mandible was a significant difference ($P = 0.003$ and $P = 0.002$, respectively).

Discussion

The MCI is an easy-application index that can be broadly implemented by dentists.[2] Taguchi[15] showed that the MCI seem to be appropriate index for triaging individuals with undiagnosed low skeletal BMD or osteoporosis. Furthermore, Taguchi et al.[16] suggest that the MCI, when used for identifying asymptomatic postmenopausal female patients at risk of having osteoporosis in general dental practice,

Table 4 Mandibular cortical index using artificial intelligence-based computer-assisted diagnosis in relation to underlying diseases in women under 51 and over 50 years of age.

Underlying diseases	Mandibular cortical index using AI-CAD									
	Under 51 years of age (21—50 years, n = 229)					Over 50 years of age (51—90 years, n = 190)				
	Cases	Class 1	Class 2	Class 3	*P*-value	Cases	Class 1	Class 2	Class 3	*P*-value
Diabetes					—					0.215
Presence	0	0 (0%)	0 (0%)	0 (0%)		10	1 (10.0%)	6 (60.0%)	3 (30.0%)	
Absence	229	212 (92.6%)	14 (6.1%)	3 (1.3%)		180	67 (37.2%)	73 (40.6%)	40 (22.2%)	
Hypertension					0.961					0.269
Presence	1	1 (100%)	0 (0%)	0 (0%)		60	19 (31.7%)	30 (50.0%)	11 (18.3%)	
Absence	228	211 (92.5%)	14 (6.1%)	3 (1.3%)		130	49 (37.7%)	49 (37.7%)	32 (24.6%)	
Dyslipidemia					<0.001					0.415
Presence	1	0 (0%)	1 (100%)	0 (0%)		34	13 (38.2%)	11 (32.4%)	10 (29.4%)	
Absence	228	212 (93.0%)	13 (5.7%)	3 (1.3%)		156	55 (35.3%)	68 (43.6%)	33 (21.2%)	
Rheumatism					0.034					0.099
Presence	2	1 (50.0%)	1 (50.0%)	0 (0%)		6	1 (16.7%)	5 (83.3%)	0 (0%)	
Absence	227	211 (93.0%)	13 (5.7%)	3 (1.3%)		184	67 (36.4%)	74 (40.2%)	43 (23.4%)	
Osteoporosis					—					0.013
Presence	0	0 (0%)	0 (0%)	0 (0%)		35	5 (14.3%)	19 (54.3%)	11 (31.4%)	
Absence	229	212 (92.6%)	14 (6.1%)	3 (1.3%)		155	63 (40.6%)	60 (38.7%)	32 (20.6%)	

Abbreviations: AI-CAD, artificial intelligence-based computer-assisted diagnosis.

Table 5 Degree of deformation of mandibular inferior cortex using artificial intelligence-based computer-assisted diagnosis in relation to dental status in women under 51 and over 50 years of age.

Number of teeth present	Degree of deformation of mandibular inferior cortex using AI-CAD							
	Under 51 years of age (21–50 years, n = 229)				Over 50 years of age (51–90 years, n = 190)			
	Cases	Mean ± SD	Range	*P*-value	Cases	Mean ± SD	Range	*P*-value
Maxilla								
Total				0.838				<0.001
0 - 13	21	16.8 ± 14.4	0–65		124	49.5 ± 22.1	3–91	
14	208	16.0 ± 12.5	0–71		66	36.9 ± 22.6	1–86	
Anterior				0.436				0.023
0 - 5	9	22.1 ± 20.4	0–65		63	50.6 ± 22.3	3–90	
6	220	15.8 ± 12.3	0–71		127	42.4 ± 23.0	1–91	
Posterior				0.830				<0.001
0 - 7	17	17.2 ± 15.5	0–65		117	49.9 ± 22.3	3–91	
8	212	15.9 ± 12.5	0–71		73	37.4 ± 22.1	1–86	
Mandible								
Total				0.886				<0.001
0 - 13	15	14.9 ± 11.0	0–43		128	49.3 ± 22.0	1–91	
14	214	16.1 ± 12.8	0–71		62	36.5 ± 22.8	2–81	
Anterior				0.638				0.002
0 - 5	1	18	18		21	59.1 ± 21.7	11–91	
6	228	16.0 ± 12.7	0–71		169	43.4 ± 22.6	1–90	
Posterior				0.748				0.001
0 - 7	14	14.6 ± 11.4	0–43		127	49.1 ± 21.9	1–91	
8	215	16.1 ± 12.8	0–71		63	37.2 ± 23.3	2–81	

Abbreviations: AI-CAD, artificial intelligence-based computer-assisted diagnosis; SD, standard deviation.

may be helpful in reducing the incidence of first fractures, with a consequent reduction in the secondary fractures, medical costs, and mortality associated with osteoporotic fragility fractures, without incurring any additional cost. Therefore, we analyzed quantitatively the mandibular cortical morphology, such as the MCI, using an AI-CAD for panoramic radiography, especially focusing on underlying diseases and dental status in women over 20 years of age.

In terms of the correlation between the MCI classification and age, Ledgerton et al.[11] indicated that the MCI showed an age-related distribution in a British female population. Gulsahi et al.[12] suggested that logistic regression analysis clearly showed that age was the most important parameter for the MCI in Turkish patients, and as age increased, the likelihood of being in the Class 3 category also increased. Ogawa et al.[9] showed that the MCI of Japanese women was a significant difference for aging, although those of men was not significant difference for aging. In this study, the degree of deformation of MIC in women under 51 years of age was significantly lower than those of over 50 years of age, and the MCI was a significant difference for the different age groups. Munhoz et al.[2] concluded that this correlation is expected, as the risk for osteoporosis increases with age, and systemic BMD alterations due to osteoporosis affect the mandible, similar to how they affect other major bones. We also support those hypotheses, and consider that this correlation is expected, as the patients over 50 years of age include postmenopausal women.

In terms of the correlation between the MCI classification and underlying disease excluding osteoporosis, Munhoz et al.[17] investigated type 2 diabetes and its association with the MCI, and suggest that type 2 diabetes might increase BMD in postmenopausal females. Tenório et al.[18] concluded that the MCI suggestive of reduced BMD is more likely to be identified in panoramic radiographs of hepatic cirrhotic individuals than of healthy ones. In this study, the degree of deformation of MIC and the MCI in women over 50 years of age was a significant difference for only osteoporosis not diabetes, hypertension, dyslipidemia and rheumatism. Further research is necessary to validate these results and the relationship between MCI and underlying diseases.

Regarding the MCI in relation to dental status, Gulsahi et al.[12] indicated that compared with fully dentate patients, the likelihood of being in the Class 3 category for edentulous patients was 27.30 times higher and in partially dentate patients it was 2.68 times higher, and concluded that masticatory muscle atrophy may be one of the factors resulting in a change in the quality of mandibular bone. Taguchi et al.[13] suggest that the loss of posterior teeth may be associated with a decrease not only in alveolar bone height, but also in alveolar BMD. However, Yaşar et al.[14] were unable to show the relationship between osteoporosis and the number of teeth present. In this study, the degree of deformation of MIC and the MCI in women over 50 years of age, and the number of total teeth present in the maxilla and mandible was a significant difference. We consider that those results may indicate that local factors such as dental status affect mandibular bone quality, and patients of dental treatments may include osteoporosis who are not diagnosed and treated. Our results recommend that women with tooth loss over 50 years of age should

Table 6 Mandibular cortical index using artificial intelligence-based computer-assisted diagnosis in relation to dental status in women under 51 and over 50 years of age.

Number of teeth present	Mandibular cortical index using AI-CAD									
	Under 51 years of age (21—50 years, n = 229)					Over 50 years of age (51—90 years, n = 190)				
	Cases	Class 1	Class 2	Class 3	*P*-value	Cases	Class 1	Class 2	Class 3	*P*-value
Maxilla										
Total					0.336					0.003
0 - 13	21	19 (90.5%)	1 (4.8%)	1 (4.8%)		124	34 (27.4%)	56 (45.2%)	34 (27.4%)	
14	208	193 (92.8%)	13 (6.3%)	2 (1.0%)		66	34 (51.5%)	23 (34.8%)	9 (13.6%)	
Anterior					0.024					0.032
0 - 5	9	7 (77.8%)	1 (11.1%)	1 (11.1%)		63	17 (27.0%)	25 (39.7%)	21 (33.3%)	
6	220	205 (93.2%)	13 (5.9%)	2 (0.9%)		127	51 (40.2%)	54 (42.5%)	22 (17.3%)	
Posterior					0.227					0.004
0 - 7	17	15 (88.2%)	1 (5.9%)	1 (5.9%)		117	32 (27.4%)	52 (44.4%)	33 (28.2%)	
8	212	197 (92.9%)	13 (6.1%)	2 (0.9%)		73	36 (49.3%)	27 (37.0%)	10 (13.7%)	
Mandible										
Total					0.896					0.002
0 - 13	15	14 (93.3%)	1 (6.7%)	0 (0%)		128	35 (27.3%)	59 (46.1%)	34 (26.6%)	
14	214	198 (92.5%)	13 (6.1%)	3 (1.4%)		62	33 (53.2%)	20 (32.3%)	9 (14.5%)	
Anterior					0.961					0.002
0 - 5	1	1 (100%)	0 (0%)	0 (0%)		21	4 (19.0%)	6 (28.6%)	11 (52.4%)	
6	228	211 (92.5%)	14 (6.1%)	3 (1.3%)		169	64 (37.9%)	73 (43.2%)	32 (18.9%)	
Posterior					0.895					0.003
0 - 7	14	13 (92.9%)	1 (7.1%)	0 (0%)		127	35 (27.6%)	59 (46.5%)	33 (26.0%)	
8	215	199 (92.6%)	13 (6.0%)	3 (1.4%)		63	33 (52.4%)	20 (31.7%)	10 (15.9%)	

Abbreviations: AI-CAD, artificial intelligence-based computer-assisted diagnosis.

undergo BMD testing, such as DXA, because of a risk factor for osteoporosis.

There were several limitations of this study. Although the patients in women over 20 years of age who underwent panoramic radiography were included in this study, those patients were not investigated about pre- or post-menopause and BMD testing, such as DXA, because of dental treatments not osteoporosis. We consider that the most interesting point of the PanoSCOPE is how early to detect and diagnose osteoporosis, and the MCI may differ depending on the stages of osteoporosis. Further research on osteoporosis is necessary to validate these results.

In conclusion, this study analyzed quantitatively the mandibular cortical morphology using the AI-CAD for panoramic radiography, especially focusing on underlying diseases and dental status in women over 20 years of age. The results of this study indicated that the mandibular cortical morphology using the AI-CAD is significantly related to osteoporosis and dental status in women over 50 years of age.

Declaration of competing interest

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

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