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RESEARCH

Panoramic-based mandibular indices in relation to mandibular bone mineral density and skeletal status assessed by dual energy X-ray absorptiometry and quantitative ultrasound

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Objectives: The panoramic-based indices (Mandibular Cortical Index-MCI, the height of mandibular inferior cortex-IC (mm), Panoramic Mandibular Index-PMI, Mandibular Ratio-MR) were used to evaluate their diagnostic efficacy and to determine whether they correlate with bone mineral density (BMD (g/cm^2)) of the mandible and hip, and with ultrasound parameters of the calcaneus and hand phalanges in postmenopausal, edentulous women.
Methods: Basing on MCI women were divided into three subgroups differed in the appearance of the mandibular cortex (C1 $n=6$, C2 $n=16$, C3 $n=8$). BMD of the hip (neck-BMD, Ward's-BMD, trochanteric BMD) and mandible (m-BMD) were measured by dual-energy X-ray absorptiometry (DXA). Calcaneus using Achilles (Speed of Sound-SOS (m/s), Broadband Ultrasound Attenuation-BUA [dB/MHz], Stiffness Index-SI [%]) and hand phalanges (amplitude dependent speed of sound-Ad-SoS (m/s)) using DBM Sonic 1200 were assessed by Quantitative Ultrasound (QUS).
Results: There were no significant differences between subgroups in parameters measured except for significant differences in m-BMD ($P<0.01$). Only m-BMD correlated significantly with DXA ($r=0.43-0.45$, $P<0.05$) and QUS ($r=0.36-0.55$, $P<0.05$) measurements excluding correlations with calcaneal SOS and trochanteric BMD. The ability of the mandibular variables to discriminate between normal and osteopenic/osteoporotic cases was assessed by calculating: specificity (ranging from 31 to 81%), sensitivity (ranging from 21 to 93%), negative and positive predictive values (ranging from 47 to 83% and 40 to 79%, respectively).
Conclusion: MCI is a simple three-graded classification of changes in the cortex but is not able to distinguish normal and osteopenic/osteoporotic postmenopausal edentulous women. The efficacy of the panoramic-based mandibular indices in diagnosing osteopenia/osteoporosis is low to moderate.
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Introduction

The problems associated with age-related skeletal osteopenia have received much attention since the human skeleton undergoes a continuous physiologic decrease in bone mass with advancing age. Bone loss starts at about the age of 35 and continues at different rates throughout life. Women lose more mineralized bone than men especially after menopause when bone loss accelerates and can result in fractures, which are often the first symptoms of osteoporosis. Osteoporosis, the most common metabolic bone disease, is characterized by low bone mass, microarchitectural weakening leading to bone fragility and an increase

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in fracture risk. Bone status at various sites can be assessed using dual energy X-ray absorptiometry (DXA), quantitative ultrasound (QUS) or quantitative computed tomography (QCT).

The earliest suggestion of an association between osteoporosis and oral bone loss was made in 1960.[1] The mandible, like the maxilla, can be affected by systemic diseases or medical treatment as well as local bone diseases which can result in total loss of teeth. It is well known that the jaws undergo a continuous alveolar ridge atrophy after extraction of teeth and the use of full dentures.[2] This atrophy is about four times greater in the edentulous mandible than in the maxilla.[2] A number of investigators have stated that the progressive loss of alveolar bone may be manifestation of osteoporosis.[3–7]

The panoramic radiograph is widely used for routine examinations, especially for edentulous patients before the construction of a complete denture. In the elderly population the dentist is often the only doctor regularly visited. It would be very useful to answer whether radiographic changes in the mandible indicate skeletal osteopenia and could have a role in the detection of osteoporosis. Some authors concluded that panoramic dental radiographs should not be used to assess the patient's status regarding osteoporosis[5,8–11] or could be reliable in screening for osteoporosis.[3,9,12,13] To our knowledge, no comparisons of mandibular indices with QUS measurements at other skeletal sites have been published while such comparisons with DXA measurements were demonstrated.[9,12]

The aim of this study was to evaluate the diagnostic efficacy of the panoramic-based mandibular indices and to determine whether they correlate with bone mineral density (BMD) of the mandible and hip, and with ultrasound (US) parameters of the calcaneus and hand phalanges. A comparison of mandibular variables with different parameters reflecting general skeletal status were assessed by two methods: DXA and QUS.

Materials and methods

The participants of the study were 30 healthy, postmenopausal edentulous women aged from 48 to 71 years (mean age 59.3 SD6.2). Some of patients referred to Prosthodontic Department for complete denture construction, and the rest were volunteers recruited after advertisements in a local newspaper. The study group was derived from our previously-described subjects,[14] from a total of 64 women of which 34 were excluded: 28 women because of medical reasons known to affect bone metabolism (either diseases or medications) and six persons for the purpose of obtaining comparable subgroups. None of women were on hormonal replacement therapy (HRT) or taking calcitonin, bisphosphonates or fluorides except of low doses of calcium or vitamin D. Criteria for stomatological selection of the subjects were as follows: maxilla and mandible edentulous, no history of serious diseases impacting oral bones, use of two full dentures. Each woman had a natural menopause. No previous fractures were noted.

All women were divided into three subgroups (C1 created by six women, 20%; C2 created by 16 women, 53%; and C3 created by eight women, 27%) based on Mandibular Cortical Index (MCI) according to Klemetti *et al.* classification.[11] MCI is a three-point index (C1–C3) based on the appearance of the lower border of mandibular cortex distally from the mental foramen, as viewed on panoramic radiographs. MCI was assessed using following criteria: C1, the endosteal margin of the cortex was even and sharp on both sides; C2, the endosteal margin showed semilunar defects (lacunar resorption) or seemed to form endosteal cortical layers (one to three layers) on one or both sides; C3, the cortical layer formed heavy endosteal cortical residues and was clearly porous.

The study was approved by a local ethics committee and informed consent was obtained from all subjects.

Panoramic radiographic examination

The mandibles were examined on panoramic images taken with PM 2002 CC apparatus (Planmeca, Helsinki, Finland) by a single operator. The position of the head was standarized as much as possible.

Measurements were made with a transparent millimeter rule placed across the image of the mandible perpendicular to the horizontal axis of the mandibular body (the inferior and superior borders forming equal angles with the ruler), with the edge of the ruler adjacent to the posterior edge of the mental foramen. Three measurements were recorded:

(1) The total height of the mandibular body (the distance between lower and upper borders) (H (mm));
(2) The height from the lower border of the mandible to the lower border of the mental foramen (h (mm));
(3) The height of the mandibular inferior cortex (IC (mm)).

Based on these measurements, two panoramic-based indices were measured: Panoramic Mandibular Index (PMI) and Mandibular Ratio (MR). PMI was calculated according to the method of Benson *et al.*[15] as a ratio IC/h. MR, serving as the indicator of residual ridge resorption (RRR), was calculated as a ratio H/h according to the method of Ortman *et al.*[6] which is adaption of a technique described by Wical and Swoope.[16] Mandibular bone loss (%) was also calculated as the difference between the original height of the mandible ($3 \times h$) and the distance between lower and upper borders (H). According to Wical and Swoope[16] the distance from the lower mandibular border to the mental foramen (h) remains relatively constant throughout life and in a nonresorbed

mandible this height is about one third of the total mandibular height. By using the approximate ratio of 3 : 1, the original height of the mandible was estimated ($3 \times h$).

The panoramic radiograph of each patient was viewed twice by two independent observers. Inter- and intra-observer agreement in classification using MCI was assessed by calculation of the kappa (κ) statistic.[17] Precision of PMI and MR measurements was established on the basis on mean coefficients of variation (CV% = SD/mean × 100%). All panoramic radiographs were measured three times by another researcher. The CVs values were: 12.3% for PMI and 6.7% for MR.

DXA examinations of the mandible and hip using DPX-L densitometer (Lunar, Madison, WI, USA)
No DXA software specifically designed for the mandible is available. Thus, mandibular BMD (m-BMD (g/cm^2)) measurements were performed in the body of the mandible according to the methodology proposed by Horner *et al*.[18] All DXA scans were done by the same operator. CV% for mandibular measurements calculated on the basis of 15 measurements in five persons (three for each of them) was 2.1%. The individuals were randomly selected from women evaluated in the study. Each measurement taken for the calculation of the precision was performed with the repositioning and standing up between scans.

DXA of the right hip included BMD (g/cm^2) measurements at femoral neck (neck – BMD), Ward's triangle (Ward's – BMD) and trochanter (troch – BMD). CV% for hip measurements calculated on the basis of 50 measurements in 10 persons (five for each of them) was 2.5%.

QUS examinations of the calcaneus and hand phalanges
US measurements of the calcaneus using Achilles (Lunar, Madison, WI, USA) were performed at the right (dominant) heel. The Speed of Sound – SOS (m/s) and Broadband Ultrasound Attenuation – BUA (dB/MHz) were measured. The Achilles system calculates also a Stiffness Index – SI (%) which does not represent a biological stiffness of bone tissue. All measurements were done by the same operator. Short-term *in vivo* precision was established on the basis of 100 measurements in 20 healthy women (five for each of them). The CVs% values were: SOS, 0.22%; BUA, 1.8%; and SI, 1.1%.

Phalangeal US measurements were obtained using an Italian device DBM Sonic 1200 (Carpi, Modena, Italy) consisting of two probes mounted on an electronic caliper. The emitter probe positioned on the medial surface of the measured phalanx generates a single period at 1.25 MHz every 128 microseconds. The receiver probe is positioned on the lateral side of the phalanx and obtains the US that has crossed the phalanx. The time interval between emission and reception of the US signal was measured and expressed in m/s. We determined the speed of sound in the distal metaphyses of the proximal phalanges of the second through fifth digits of the right hand. The speed of sound in bone was calculated using the first signal with an amplitude more than 36 pixels on the screen. Thus, the measured speed of sound was dependent on signal amplitude (Amplitude-dependent Speed of Sound – Ad-SoS). Acoustic coupling was achieved using a standard ultrasound gel. All measurements were done by the same person. *In vivo* short-term precision was established on the basis of 75 measurements made in 15 healthy persons (five for each of them) by the same operator. CV% was 0.64%.

Statistical analysis
Calculations of means and standard deviations (SD) as well as correlations and differences were performed using Statistica program (StatSoft, Tulsa, OK, USA). Correlations between variables studied were established using the Pearson correlation coefficient and correlations between MCI (C1 – C3) and other variables using non-parametric Spearman correlations. Kruskall – Wallis test was used to assess the differences between subgroups C1, C2 and C3. The sensitivity (probability that a test result will be positive when the disease is present; true positive rate), specificity (probability that a test result will be negative when a disease in not present; true negative rate), negative predictive value (probability that the disease in not present when the test is negative) and positive predictive value (probability that the disease is present when the test is positive) of the mandibular variables in diagnosing osteopenia/osteoporosis were tested with dichotomous 2×2 tables. The significant level was achieved with P value < 0.05.

Results

Subgroups did not differ significantly in regard to age, weight, height, years since menopause (YSM) and edentulous years. Clinical characteristics of all women and subgroups studied are presented in Table 1.

Mean values ($\pm$SD) of parameters studied for all group and three subgroups C1 – C3 are shown in Table 2. There were no significant differences between subgroups in parameters measured except for significant differences in m-BMD ($P < 0.01$). Mean m-BMD was 1.24 SD0.26 g/cm^2. Most parameters studied did not decrease significantly with change of cortical appearance (from C1 to C3) while mandibular bone loss increased with mean loss of 34.6 SD15.9%. The height from the lower border of the mandible to the lower border of the mental foramen (h) was stable with mean value of 12.3 SD2.0 mm. Most correlations of MCI (i.e. the severity of cortical change classes from C1 to C3), the height of IC, PMI, MR and m-BMD with other variables in all women were not significant

Table 1 Clinical characteristics of women studied

	All women mean SD n = 30	*Subgroup C1 mean SD* n = 6	*Subgroup C2 mean SD* n = 16	*Subgroup C3 mean SD* n = 8
Age (years)	59.3 (6.2)	56.7 (7.6)	59.1 (6.6)	61.9 (3.3)
Weight (kg)	70.7 (11.7)	70.2 (13.8)	69.1 (10.3)	74.5 (13.4)
Height (m)	1.58 (0.06)	1.58 (0.04)	1.58 (0.05)	1.58 (0.08)
YSM (years)	10.2 (6.6)	9.7 (7.2)	9.1 (6.7)	12.7 (6.1)
Years edentulous (years)	9.9 (10.1)	5.2 (4.0)	12.5 (11.8)	8.1 (8.7)

YSM: years since menopause. No significant differences between subgroups

Table 2 Mean values of parameters studied

	All women mean SD n = 30	*Subgroup C1 mean SD* n = 6	*Subgroup C2 mean SD* n = 16	*Subgroup C3 mean SD* n = 8
m-BMD (g/cm^2)	1.24 (0.26)	1.43 (0.28*)	1.25 (0.27*)	1.06 (0.10*)
neck-BMD (g/cm^2)	0.86 (0.12)	0.94 (0.13)	0.85 (0.11)	0.84 (0.13)
T-score	−0.96 (1.02)	−0.28 (1.12)	−1.12 (0.91)	−1.17 (1.10)
Z-score	0.003 (0.87)	0.51 (1.02)	−0.15 (0.80)	−0.07 (0.83)
Ward's-BMD	0.74 (0.14)	0.84 (0.14)	0.71 (0.13)	0.71 (0.12)
T-score	−1.32 (1.05)	−0.50 (1.08)	−1.52 (0.99)	−1.53 (0.94)
Z-score	0.007 (0.85)	0.62 (0.91)	−0.20 (0.86)	−0.03 (0.61)
troch-BMD	0.79 (0.14)	0.85 (0.20)	0.76 (0.10)	0.79 (0.17)
T-score	−0.04 (1.31)	0.54 (1.80)	−0.27 (0.95)	−0.02 (1.56)
Z-score	0.38 (1.07)	0.85 (1.34)	0.16 (0.87)	0.43 (1.20)
Ad-SoS (m/s)	1945 (60)	1958 (75)	1955 (59)	1912 (43)
SOS [m/s]	1511.9 (25.0)	1517.3 (31.4)	1509.9 (23.1)	1511.8 (26.8)
BUA (dB/MHz)	104.0 (9.0)	110.4 (10.2)	103.0 (9.5)	101.1 (4.5)
SI (%)	72.7 (11.2)	78.5 (14.5)	71.4 (10.8)	70.7 (9.0)
IC (mm)	4.71 (1.49)	5.27 (0.86)	4.85 (1.49)	4.00 (1.75)
PMI	0.38 (0.13)	0.42 (0.06)	0.39 (0.12)	0.33 (0.19)
MR	1.87 (0.48)	2.16 (0.58)	1.84 (0.44)	1.70 (0.44)
Mandibular bone loss (%)	34.6 (15.9)	23.1 (12.1)	36.1 (15.2)	40.4 (17.0)

(m/troch-)BMD: (mandibular/trochanter) bone mineral density; T-score: SD decrease from peak bone mass; Z-score: SD decrease/increase from age-matched normals; Ad-SoS: amplitude dependent speed of sound; SOS: speed of sound; BUA: broadband ultrasound attenuation; SI: stiffness index: IC, the height of the mandibular inferior cortex; PMI: panoramic mandibular index; MR: mandibular ratio. *Significant differences between subgroups $P<0.01$

including all correlations with age and YSM. MCI correlated significantly with m-BMD ($r=-0.55$, $P<0.002$), with the height of IC ($r=-0.38$, $P<0.04$) and with mandibular bone loss ($r=0.36$, $P<0.05$), PMI correlated with the height of IC ($r=0.82$, $P<0.000001$) as expected, and MR with years edentulous ($r=-0.52$, $P<0.01$) and with mandibular bone loss ($r=-0.88$, $P<0.001$). Only m-BMD correlated significantly with the most skeletal parameters: with Ad-SoS ($r=0.36$, $P<0.05$), BUA ($r=0.55$, $P<0.001$), SI ($r=0.45$, $P<0.05$), neck – BMD ($r=0.43$, $P<0.05$), and Ward's – BMD ($r=0.45$, $P<0.01$) excluding correlations with calcaneal SOS and trochanteric BMD. Above correlations were not calculated separately for subgroups because of too small a sample size.

All women were also divided into three skeletal mineral density groups on the basis of DXA measurements of the hip according to the WHO criteria: normals defined as a T-score to 1 SD below the normal young female value ($n=16$), osteopenics defined as T-score ranging from 1 to 2.5 SD below that value ($n=12$) and osteoporotics defined as T-score more than 2.5 SD below above value ($n=2$). Their characteristics are presented in Table 3. Because of the small number of osteoporotic patients they were combined with osteopenics into one group ($n=14$). Such division allowed the assessment of the mandibular variables to discriminate between normal and osteopenic/osteoporotic cases by calculating: specificity (ranging from 31 to 81%), sensitivity (ranging from 21 to 93%), negative and positive predictive values (ranging from 47 to 83% and 40 to 79%, respectively) (Table 4 – 8). The combination of the height of IC and MCI did not improve this ability (Table 9).

The results of the assessment of intra- and inter-observer agreement in the classification of radiologic appearance by MCI are shown in Table 10.

Discussion

MCI based on the appearance of the lower border of mandibular cortex is a simple classification based on the panoramic radiograph. Contrary to MCI, the PMI and MR need to record some measurements on panoramic radiographs and then some calculations. Because of this they are more time-consuming and complicated than estimation of the height of the mandibular inferior cortex or MCI that distinguishes

Table 3 Frequencies of cortical changes (C1–C3) and means of mandibular variables in skeletal mineral density groups

	Normals (n = 16)	*Osteopenics* (n = 12)	*Osteoporotics* (n = 2)
C1	$n = 5$ (31%)	$n = 1$ (8%)	$n = 0$
C2	$n = 7$ (44%)	$n = 8$ (67%)	$n = 1$ (50%)
C3	$n = 4$ (25%)	$n = 3$ (25%)	$n = 1$ (50%)
m-BMD (g/cm^2)	1.32 (0.23*)	1.16 (0.28*)	1.02 (0.29*)
PMI	0.34 (0.16)	0.43 (0.08)	0.37 (0.02)
IC	4.52 (1.86*)	5.1 (0.79*)	3.50 (0.00*)
MR	1.80 (0.41)	1.98 (0.58)	1.78 (0.46)

*Significant differences with $P < 0.05$

Table 4 The ability of MCI to discriminate between normals and osteopenics/osteoprotics

MCI	*Normals*	*Osteopenics/osteoporotics*	*Total*
C1	5	1	6
C2, C3	11	13	24
Total	16	14	30
Sensitivity	93%	Specificity	31%
Positive predictive value	54%	Negative predictive value	83%

Table 5 The ability of 4-mm-high mandibular cortex to discriminate between normals and osteopenics/osteoprotics

IC	*Normals*	*Osteopenics/Osteoporotics*	*Total*
>4 mm	13	11	24
<4 mm	3	3	6
Total	16	14	30
Sensitivity	21%	Specificity	81%
Positive predictive value	50%	Negative predictive value	54%

Table 6 The ability of PMI to discriminate between normals and osteopenics/osteoporotics

PMI	*Normals*	*Osteopenics/osteoporotics*	*Total*
>0.33	13	3	16
<0.33	3	11	14
Total	16	14	30
Sensitivity	79%	Specificity	81%
Positive predictive value	79%	Negative predictive value	81%

Table 7 The ability of MR to discriminate between normals and osteopenics/osteoporotics

MR	*Normals*	*Osteopenics/osteoporotics*	*Total*
>1.78	7	8	15
<1.78	9	6	15
Total	16	14	30
Sensitivity	43%	Specificity	44%
Positive predictive value	40%	Negative predictive value	47%

three classes (C1–C3) by the severity of cortical changes. Our 30 women were classified into the MCI subgroups, which did not differ significantly in variables measured except for the mandibular BMD ($P < 0.01$). We observed only the tendency to have

Table 8 The ability of mandibular BMD to discriminate between normals and osteopenics/osteoporotics

m-BMD	*Normals*	*Osteopenics/osteoporotics*	*Total*
>1.200	12	7	19
<1.200	4	7	11
Total	16	14	30
Sensitivity	50%	Specificity	75%
Positive predictive value	64%	Negative predictive value	63%

Table 9 The ability of MCI and height of mandibular cortex in combination to discriminate between normals and osteopenics/osteoporotics

Combination	*Normals*	*Osteopenics/osteoporotics*	*Total*
C1 and IC>4 mm	5	1	6
C2, C3 and IC<4 mm	3	3	6
Total	8	4	12
Sensitivity	75%	Specificity	62%
Positive predictive value	50%	Negative predictive value	83%

Table 10 Intra- and inter-observer agreement in assessment of MCI, quantified by Cohen's kappa (κ)

	κ
Intra-observer agreement (observer 1)	0.75
Intra-observer agreement (observer 2)	0.66
Inter-observer agreement	0.70

$\kappa < 0.40$ poor agreement, $\kappa = 0.41–0.60$ moderate agreement, $\kappa = 0.61–0.80$ substantial agreement, $\kappa > 0.75$ almost perfect agreement

thinner cortex and lower values of PMI, MR and parameters reflecting skeletal status with the change classes (from C1 to C3) of the cortical appearance (except for trochanteric BMD and calcaneal SOS). MCI values correlated positively with mandibular bone loss ($r = 0.36$, $P < 0.05$). Mean mandibular bone loss was 34.6 SD15.9% and even 40.4 SD17.0% in subgroup C3. This bone loss did not appear to be connected with age, YSM and skeletal status. Only correlation with MR ($r = -0.88$, $P < 0.001$) was significant. No comparison with results of other authors is possible because of the lack of such published data. MCI correlated negatively with the height of IC ($r = -0.38$, $P < 0.04$) and with m-BMD ($r = -0.55$, $P < 0.002$). Also in Horner and Devlin study[19] of 40 edentulous women MCI significantly correlated with m-BMD ($r = -0.48$, $P = 0.001$ and

$r=-0.50$, $P=0.002$). In our study all correlations of MCI with DXA and QUS measurements were not significant. Our results suggest that MCI reflects mandibular BMD but not skeletal status.

Watson *et al*.[8] showed no differences in the mean PMI between normal and osteoporotic women aged 54–71 years (0.38 and 0.37, respectively). Also our women divided into normals, osteopenics and osteoporotics that did not differ significantly in the mean PMI (0.34, 0.43, 0.37, respectively). They differed significantly in the height of mandibular cortex (4.5 mm, 5.1 mm, 3.5 mm, respectively, $P<0.05$). Similarly, Bollen *et al*.[13] found that the cortex was significantly thinner in subjects with osteoporotic fractures compared with controls but in Mohajery *et al*.'s study[10] cortical bone thickness did not differentiate postmenopausal osteoporotic women from those without disease. We noted no correlations of PMI and the height of mandibular cortex with DXA and QUS measurements. Contrary to us, in Taguchi *et al*.'s study[12] there was a significant negative correlation between the width of the mandibular inferior cortex and spinal BMD ($r=-0.36$, $P<0.001$). Also in Klemetti *et al*.'s study[9] correlations between the PMI and BMD of the femoral neck and spine measured by DXA in 355 women were weak, but significant ($r=0.20-0.24$, $P<0.001$). The authors concluded that it is difficult to find a strong positive correlation between the PMI and the general mineral status of the skeleton in a population of postmenopausal middle-aged women. However, PMI can perhaps be used as an indicator of bone mineral changes when the PMI values deviate markedly from the mean PMI of the population.

Hirai *et al*.[3] suggested in the study of 44 female and male edentulous patients aged 81.1 years that osteoporosis strongly affects reduction of the residual ridge. The height of the residual edentulous ridge in these patients was significantly correlated ($r=-0.42$, $P<0.01$) with the severity of osteoporosis. In our study all correlations of MR with parameters reflecting skeletal status measured by DXA and QUS were not significant. Any data concerning these correlations for MR were not published and comparison is not possible. We noted only two significant correlations of MR: with mandibular bone loss ($r=-0.88$, $P<0.001$) and with years edentulous ($r=-0.52$, $P<0.01$). The last-mentioned correlation corresponds to observation by Ortman *et al*.[6] that the percentage of patients with severe RRR increases with time edentulous.

Among mandibular variables only m-BMD correlated significantly with densitometric ($r=0.43-0.45$) and ultrasound measurements ($r=0.36-0.55$) excluding trochanteric BMD and calcaneal SOS. It confirms earlier observations that mandibular BMD may be an appropiate measurement site for evaluation of skeletal status in osteoporosis.[12,18] Mandibular BMD differed significantly between normal, osteopenic and osteoporotic women ($P<0.05$) such as the height of mandibular cortex. We noted also significant differences in m-BMD between subgroups C1 and C3 and between C2 and C3 ($P<0.01$), similarly to results obtained by Horner and Devlin ($P<0.05$).[19]

It is worth emphasizing that the practical difficulties associated with scanning patients at the mandibular site are the limitation of the clinical use of m-BMD. The mandible is a difficult site to perform conventional methods of bone densitometry because positioning and scanning need considerable skills of the operator. Also some patients may find the positioning uncomfortable and difficult to maintain during a scan time.

The ability of mandibular variables to discriminate between normal and osteopenic/osteoporotic subjects was generally low to moderate. The PMI revealed the best specificity, sensitivity, negative and positive predictive values (81%, 79%, 81%, 79%, respectively) (Table 6). Also 4-mm-high mandibular cortex gave the same specificity (81%) but sensitivity was only 21% (Table 5). The sensitivity of MCI was even 93% but specificity only 31%. MCI gave the greatest probability (83%) that osteopenia/osteporosis is not present when the test is negative (the presence of C1 cortical appearance) but probability that osteopenia/osteoporosis is present in women with C2 or C3 cortical appearance was only 54% (Table 3). Only in one study[11] we found data concerning the sensitivity and specificity of MCI, height of mandibular cortex and PMI generally low values (16 to 96%). Neither the mean cortex height, the mean PMI, nor the ordinal cortex classification (C1–C3) was able to distinguish skeletal mineral status groups. To our knowledge any data concerning specificity and sensitivity of MR have not been published. Our results show that MR is not helpful in diagnosing osteopenia/osteoporosis. All values were about 45% (Table 7).

There are published data about the problems with repeatability of radiomorphometric indices. Most authors concluded that there are limitations in repeatability of MCI or PMI assessments which might limit their usefulness in clinical practice.[19–22] There was poor to moderate agreement in MCI assessment ($\kappa=0.30-0.54$) between two observers in the Horner and Devlin study.[19] Another of their studies cast considerable doubt on the potiential value of radiomorphometric indices given their lack of precision.[21] On the other hand excellent intra-observer agreement in MCI assessments[23] and the reproducibility of MCI being 98%[11] were also noted. In our study we observed substantial both intra- and inter-observer agreement ($\kappa=0.66-0.75$), better than moderate and worse than almost perfect (Table 10). It seems to be sufficient to use MCI in clinical practice with a trained observer.

Limitations of the study are: small sample size, poor precision of PMI and MR measurements expressed using CV%, the small number of osteoporotic patients with T-score <-2.5, the lack of data for men. We are planning to study a bigger group of patients in both genders with larger proportion of osteoporotic individuals.

In conclusion MCI is a simple three-graded classification of the changes in the cortex but is not

able to distinguish normal and osteopenic/osteoporotic postmenopausal edentulous women. MCI reflects mandibular BMD but does not skeletal status. The height of mandibular inferior cortex, PMI and MR do not correlate significantly with DXA and QUS measurements and they should not be used as indicators of skeletal status. However, they reveal a tendency to decrease with the change of classes C1–C3 of the mandibular cortex such as skeletal parameters. The efficacy of the panoramic-based mandibular indices in diagnosing osteopenia/osteoporosis is low to moderate.

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