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Relationship between the mandibular cortical index and calcaneal bone mineral density in postmenopausal women

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ABSTRACT

Background and objective: In clinical practice, a comparative analysis of bone mineral density (BMD) is carried out by examining different skeletal bones. This is useful for screening of postmenopausal osteoporosis (OP). The objective of this study was to determine the relation between the mandibular cortical index (MCI) and calcaneal BMD among postmenopausal women.

Materials and methods: The study sample included 129 randomly selected postmenopausal women aged 50–77 years. The participants were examined using panoramic radiography for the analysis of the cortical layer in the mandibular base for MCI determination and using DXL for the examination of calcaneal BMD. According to T scores, the subjects were divided into three groups (Groups 1, 2, and 3). The panoramic radiographic examination of the mandible was performed; the MCI was determined and distributed into groups (C1; C2; C3). The MCI validity in determining the calcaneus BMD status was analyzed.

Results: The differences in BMD were statistically significant between Groups C1 and C3 ($P < 0.01$), Groups C2 and C3 ($P = 0.01$), and between the calcaneal BMD groups ($P < 0.001$). There was a statistically significant inverse correlation between the MCI and calcaneal BMD ($r = -0.3$; $P < 0.001$). The changes characteristic of Group C2 were documented more frequently than those of other morphological groups. The analysis of the MCI validity in BMD status showed low sensitivity (69.4%) and specificity (53.9%).

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Conclusions: The relation between MCI and calcaneal BMD was determined. The diagnostic discrimination of the MCI was found to be not sufficient in screening the women with postmenopausal osteoporosis and its application in clinical practice might be limited.

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1. Introduction

Osteoporosis (OP) is a chronic disease that affects the bone tissue of the skeleton. It is common in a significant part of the elderly population, especially in postmenopausal women [1]. Progression of bone destruction occurs 5–10 years after menopause due to estrogen deficiency and increased levels of cytokines. During the first 5 years of the postmenopausal period, bone mass can be reduced by 20% (approximately 2%–3% of trabecular bone [TB] and 1%–2% of cortical bone [CB]) [2]. Due to the difference in the distribution of TB and CB, different remodeling takes place in different bones at different time. The areas with a higher amount of TB (e.g., spine, hip, calcaneus) are more susceptible to the development of osteoporotic processes, but bone changes and reduction also occur in those skeletal bones where the content of CB is high, e.g., in the mandible [3]. A comparative analysis of bone mineral density (BMD) is carried out in clinical practice by examining different bones due to uneven skeletal bone resorption [4]. Due to its availability and simplicity, panoramic radiography is a method frequently applied in dentistry, its significance in bone changing by OP has been adequately analyzed [5]. Scientific sources indicate that by analyzing CB of the mandible using panoramic radiographic images, it is possible to diagnose the total skeletal BMD reduction in up to 95% of cases [6]. In panoramic radiographic images, the mandibular cortical index (MCI) according Klemetti could be identified and it shows the solidity of the mandibular cortical bone layer at the base and the morphological changes occurring in the development of OP [7]. Some authors have reported that the index is useful for the screening of postmenopausal patients with osteoporosis and is well correlated with skeletal bone loss [8,9]. Other researchers discussed MCI efficacy and concluded that a large sample size was needed in order the index would be useful in BMD studies and that in other cases, it was not sufficiently precise for evaluation [5,10].

The relation of MCI to different skeletal bones (spinal, hip, hand phalanges) BMD has been investigated in a variety of scientific articles; however, the data on the interrelation between this index and calcaneal BMD are scarce [11–15]. Numerous studies of calcaneal BMD include its investigation using a quantitative ultrasound method (QUS) [13–15]. Calcaneal BMD can be studied using DXL Calscan, a mobile peripheral dual-energy X-ray and laser osteodensitometer. The device was approved for diagnostic testing in 2004 [16]. To our knowledge, there are no data concerning the determination of the relationship between calcaneal BMD using DXL and MCI in the postmenopausal female population.

Therefore, the aim of this study was to determine the relation between the MCI following Klemetti according

to panoramic radiograms and calcaneal BMD, measured using a DXL Calscan osteodensitometer, in postmenopausal women.

2. Materials and methods

The study was performed in the Institute of Endocrinology and the Department of Dental and Oral Diseases at the Lithuanian University of Health Sciences with the permission of the Regional Biomedical Research Ethics Committee (No. BE-2-13). Written informed consent for participation in the study was obtained from participants who were postmenopausal females at the age of 50–77 years. A questionnaire to collect data on the participants' age, usage of bone tissue metabolism preparations, causes and duration of the postmenopausal period, general disorders of the body that might affect bone tissue changes, and daily physical activity was employed. The inclusion criteria were good general health status, 1 year free of the use of bone metabolism-affecting medications, and no diseases leading to secondary OP, cigarette smoking, or alcohol abuse. The main exclusion criteria were lack of motivation to participate in the study, surgical treatment of the mandible, periodontal disease within previous 6 months, and edentulous mandible due to non-functioning mechanical load, as this may influence bone loss [17].

2.1. Examination of BMD in the calcaneus

Calcaneal BMD was examined using DXL Calscan (P/N 031000; Demetech AB, Solna, Sweden). The device irradiation dose was 0.2 μ Sv. For examination, the participants were recommended to choose the calcaneus of a leg (left or right) without pain or previous fractures. The calcaneus was placed in the foot compartment of DXL Calscan. The software of the DXL Calscan device automatically calculated the region of interest (ROI) where calcaneal BMD had to be evaluated. The measurement results of bone mineral changes were graphically presented on the computer monitor. As the T-score determined during DXL Calscan examination met the criteria set by the WHO, the participants did not undergo any additional vertebral densitometry [18,19]. According to calcaneal BMD, the participants were divided into the following groups: Group 1, participants with normal BMD (T-score >-1); Group 2, participants with osteopenia (T-score ≤ -1 to >-2.5); and Group 3, participants with osteoporosis (T-score ≤ -2.5).

2.2. Panoramic radiographic examination

Panoramic radiograms were performed the next day after the DXL investigation.

For the identification of the MCI, panoramic radiograms were made acquired a Panoramic PC-1000 X-ray machine (Panoramic Corporation, Fort Wayne, IN). The exposure time was 14 s (the same in all cases); anodic current, 6 mA (the same in all cases); and anodic voltage, 80–85 kV, depending on the participant's build. The images were scanned and digitized at the resolution of 300 dpi and 8 bits/pixel grayscale format by applying a logarithmic algorithm. The endosteal margin of mandibular cortical bone was studied more distally on the left and right sides of the mandible mental foramen.

Klemetti et al. in 1994 proposed the classification of morphological changes in the cortical bone at the mandibular base into three groups: C1, the endosteal margin of the cortical bone is even and sharp on both sides; C2, the endosteal margin shows semilunar defects (lacunar resorption) or seems to form the endosteal cortical layer (one to three layers) on one or both sides; and C3, the cortical layer forms heavy endosteal cortical residues and is clearly porous [7]. Therefore, during the examination of the mandibular cortical bone layer, patients were divided into three morphological groups: C1, C2, and C3.

Each panoramic radiographic image was analyzed three times by the intraobserver and two independent interobservers, having the same experience in radiology in a blinded fashion. Inter- and intraobserver variations were calculated using a continuous scale.

To determine the sensitivity and specificity of the MCI, the obtained data were classified into two groups: normal and osteopenia + osteoporosis.

2.3. Statistical analysis

Statistical data analysis was performed using Statistica v. 5.5 (StatSoft, Inc., Tulsa, OK), Excel v. 2007 (Microsoft Corporation, Albuquerque, NM), and SPSS® v. 18.0 (SPSS, Chicago, IL). The coded data on the patients were used in the analysis.

The sample size was calculated during a pilot study based on the MCI value. The power (β) of 0.8 was selected for the study; and the level (α) of significance was set at 0.05.

The Kolmogorov-Smirnov test was employed to verify the distribution of quantitative values. When the sample size was sufficient and the distribution normal, differences between mean values of the groups for independent samples were compared by applying the Student t test.

Mean values and dispersions of several groups were compared by applying Kruskal-Wallis nonparametric ANOVA.

The relationship between variables was evaluated by using a Pearson correlation coefficient (r).

To analyze the validity of MCI in the diagnosis of reduced calcaneal BMD status, the sensitivity, specificity, positive and negative predictive values of mandibular cortical bone were obtained with dichotomous 2 × 2 tables.

The significance level of 0.05 was chosen.

3. Results

In total, 129 postmenopausal women aged from 50 to 77 years were examined. The mean age of the study population was 62.5 (SD 6.1) years; 38% of them were aged 60–64 years. The mean age of the participants in Groups 1 and 2 was 59.4 (SD, 6.4) and 62.3 (SD, 5.0) years, respectively. The women with osteoporosis (Group 3) were oldest (mean age, 66.4 years; SD, 6.1). All the groups differed significantly by the mean age ($F = 12.5$; $df = 2$; $P = 0.001$). There was a significant inverse correlation between calcaneal BMD and age ($r = -0.4$; $P < 0.001$).

Table 1 shows the mean calcaneal BMD and T scores by different groups. The differences in calcaneal BMD among all the groups were statistically significant to (ANOVA $F = 285.3$; $df = 2$; $P < 0.001$).

The general mean duration of the postmenopausal period was 12.5 (SD, 6.5) years. No clinical cases with menopause caused by chemotherapy, radiotherapy, or medications were documented. Table 2 shows the mean calcaneal BMD, age, and duration of the postmenopausal period by the MCI groups. ANOVA analysis revealed that the differences in the duration of the postmenopausal period ($F = 10.4$; $df = 2$; $P < 0.001$) and calcaneal BMD ($F = 5.6$; $df = 2$; $P < 0.01$) were significant comparing all the MCI groups.

The intraobserver and interobserver variations of panoramic radiographic images were 8.1% (–7.0% to 8.9%) and 13.4% (–14.2% to 15.2%), respectively.

The MCI statistically significantly correlated with calcaneal BMD ($r = -0.3$, $P < 0.001$) and duration of the postmenopausal period ($r = 0.4$, $P < 0.001$).

The distribution of the women by different calcaneal BMD and MCI groups is shown in Table 3. The analysis of the MCI validity in determining the calcaneus BMD status showed poor sensitivity and specificity of the index (Table 4).

Analysis of the answers to the questions in the questionnaire revealed that the majority of women used calcium

Table 1 – Calcaneal BMD and T score by different groups.

Variable	Group 1 N = 34	Group 2 N = 65	Group 3 N = 30	Total N = 129	P
Calcaneal T score	–0.1 (0.6)	–1.8 (0.4)	–2.9 (0.5)	–1.6 (1.1)	1 vs. 2, <0.001 2 vs. 3, <0.001 1 vs. 3, <0.001
Calcaneal BMD, g/cm ²	0.5 (0.04)	0.4 (0.03)	0.3 (0.03)	0.4 (0.1)	1 vs. 2, <0.001 2 vs. 3, <0.001 1 vs. 3, <0.001

Values are mean (standard deviation). Group 1, subjects with normal BMD (T-score >–1); Group 2, subjects with osteopenia (T-score ≤–1 to >–2.5); and Group 3, subjects with osteoporosis (T-score ≤–2.5).

Table 2 – Calcaneal BMD, age and duration of the postmenopausal period by MCI groups.

Variable	C 1 N = 17	C 2 N = 68	C 3 N = 44	Total N = 129	P
Calcaneal BMD, g/cm ⁻²	0.41 (0.06)	0.39 (0.08)	0.35 (0.07)	0.38 (0.07)	C1 vs. C2, 0.19 C1 vs. C3, <0.01 C2 vs. C3, 0.011
Age, years	58.13 (6.64)	62.83 (6.00)	63.33 (5.11)	62.38 (5.99)	C1 vs. C2, <0.01 C1 vs. C3, <0.01 C2 vs. C3, >0.05
Duration of postmenopausal period, years	7.18 (5.21)	12.13 (6.28)	14.42 (6.39)	12.42 (6.39)	C1 vs. C2, <0.01 C1 vs. C3, <0.001 C2 vs. C3, <0.05

Values are mean (standard deviation). C1, MCI group, the endosteal margin of the cortical bone was even and sharp on both sides; C2, MCI group, the endosteal margin showed semilunar defects or seemed to form endosteal cortical layer on one or both sides; C3, MCI group, the cortical layer formed heavy endosteal cortical residues and was clearly porous.

preparations inconsistently. More than three-fourths (75.9%) of the women were physically active longer than an hour a day; the remaining participants were engaged in physical activity up to 60 min.

4. Discussion

The review of scientific literature showed that calcaneal BMD in comparison to the BMD of the lumbar spine and the hip was less frequently analyzed in scientific comparative BMD research. BMD of the calcaneus as a topographically convenient area to study BMD has not been thoroughly investigated using different methods or compared to the BMD of other bones in different populations. Therefore, the object of this research – calcaneal BMD – was purposefully selected, and the use of DXL Calscan made this study more innovative.

In addition, in studies on BMD, the calcaneus has a great advantage compared to other skeletal bones: it is a skeletal bone that possesses the greatest amount of TB (95% of TB and 5% of CB), and the measurements are not affected by different additional factors, such as spinal deformations and fractures [20]. The reliability of the diagnostic possibilities of calcaneal BMD and its relation to other skeletal bones was noted in the study by Martini et al. and Salminen et al., and Yamada et al. and Xu et al. confirmed the identification of calcaneal BMD to be an effective and accurate method in the diagnostic model of osteoporosis, allows the diagnosis of the fractures in lumbar spine as well as hip [21–26]. In the studies described, calcaneal BMD was determined using QUS, single and dual-energy X-ray absorptiometry, and DXL.

In scientific literature we have not found any study that performed comparative analysis of calcaneal BMD measured using a DXL Calscan osteodensitometer and the morphological changes in the mandibular cortical bone. Thus, the results reported in this study will extend the knowledge in the analysis of general skeletal BMD. Due to the structure of the calcaneal bone, calcaneal BMD evaluated with the DXL Calscan device better reflects the BMD changes developed in the spine or the hip than in the other sites examined by applying peripheral osteodensitometric techniques, and so this device is especially suitable for choosing preventive measures, and is reliable in the diagnosis of postmenopausal OP [27,28]. Cifti et al. reported that the sensitivity of this investigation in the diagnostics of OP may be as high as 99% [29]. The diagnostic criteria of DXL Calscan were investigated by Thorpe and Steel [28] as well as Williams and Daymond [30]. Kullenberg and Falch evaluated the results of the calcaneal BMD measured by DXL and indicated that the T-score determined during this examination met the criteria set by the WHO, and the technique was proved to be optimal and accurate in the diagnosis of OP [18].

Panoramic radiography is important for maxillofacial analytical research because the possibilities to use digital technologies allow accurate determination and analysis of morphological changes in anatomic structures including changes in the cortical bone layer of the mandibular base related to the deviations in the total skeletal bone mineral density. We agree with Watanabe et al. that the method for screening should “be simple and usable even without having any special skills or requiring complicated operation,” and cheap [31]. In clinical practice, a dentist with some additional knowledge has sufficient information from a panoramic radiographic view to identify people with skeletal BMD changes [32,33]. On panoramic radiographs, the MCI is assessed on both sides of the mandible more distally to the mental foramen. We think that this anatomical area has a diagnostic value in such investigations. During the analysis of panoramic radiographic images in other regions of the mandible, some methodological problems may occur. The mental foramen is not covered by other anatomic structures, and the cortical bone of the mandibular base is not affected by the muscle attachment; therefore, there is no risk for the

Table 3 – The distribution of subjects by different calcaneal BMD and MCI groups.

Calcaneal BMD group	MCI group		
	C1	C2	C3
Group 1	8	20	6
Group 2	8	34	24
Group 3	1	14	14

Table 4 – The MCI validity in calcaneal BMD status.

MCI	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Accuracy
C ₁ vs. C ₂ +C ₃ groups in calcaneus	69.4%	53.9%	36.4%	23.9%	65.4%
MCI, mandibular cortical index; C1, C2, and C3, MCI groups.					

development of local bone osteopenia, the vertical and horizontal coefficient of radiographic image magnification in this region is constant while in different places of panoramic radiogram image magnification depends on the geometry of the mandible [34–38].

The MCI according to Klemetti reflects the solidity of cortical bone in the mandibular base. Structural changes in cortical bone tissue are manifested by the resorption both on the outer and inner sides of the mandibular cortical layer. The cavities in the inner layer of the cortical bone are formed in the areas where there is a rapid metabolism and intracortical resorption takes place [39].

The results of this study indicated that MCI had a relationship with calcaneal BMD, but the validity of the MCI in discriminating normal from osteopenic + osteoporotic cases showed low sensitivity (69.4%) and specificity (53.9%). We agree with Marandi et al. that this index may be useful for the evaluation of BMD status in patients, but is not precise in all cases [10].

The analysis of calcaneal BMD and MCI groups reflects changes in different bones: because of osteoporotic processes, BMD decreases in the calcaneal trabecular bone; however, at the same time, stratification and intracortical resorption at the mandibular cortical bone increase. However, analysis of the data also shows that in cases with normal calcaneus BMD, mandibular CB may be altered and have the changes characteristic of all MCI groups. The probability to detect mandibular CB stratification up to 3 layers is higher than that to identify other morphological changes. The results of the study show that morphological changes characteristic of groups C2 and C3 were documented more frequently in groups 2 and 3.

The results of this study cannot be compared to the data of other articles, because to our knowledge, no analogous study has been performed. The majority of studies investigating bone changes compare the MCI with (i) DXA of the spine, (ii) DXA of the hip, (iii) DXA of other bones BMD, or (iv) calcaneal BMD obtained by QUS [11–15].

While investigating the relationship between calcaneal BMD measured by QUS and MCI, no significant correlation in the postmenopausal edentulous female group was identified in the study by Drozdowska et al. [15]. The authors concluded that the MCI reflected mandibular BMD, but not skeletal status and also that the repeatability of MCI assessments might limit usefulness of the index in clinical practice.

We found that only one woman with osteoporosis had an even and unchanged endosteal cortical layer, while some morphological changes with features characteristic of Groups C2 and C3 were observed in other study participants. This confirms the statement by Taguchi et al. that even if there are no morphological changes in the mandibular cortical bone tissue, a woman may still belong to the risk group of decreased

BMD [40]. It is worth noting that in one of many studies by Taguchi et al., none of the postmenopausal age females (age group of 50–70 years) had morphological changes in the mandibular cortical tissue characteristic of Group C3 [41].

Our study showed that women with normal calcaneal BMD could be assigned to all three morphological MCI groups. These data are in line with the findings of Halling et al., who investigated calcaneal BMD using DXA [42].

It should be mentioned that the MCI has a relationship with the age and duration of the postmenopausal period. The greatest morphological changes in the mandible base were detected in women with the longest postmenopausal period, and their mean age was the highest. Yüzügüllü et al. reported that the greatest morphological changes – stratification and porosity (group C3) – in the cortical bone tissue of the mandibular base were diagnosed in postmenopausal women aged more than 60 years ($P < 0.01$) [43]. In this study, the women of the same age were diagnosed not only with inner surface stratification (C2), but also with heavy endosteal cortical residues (C3).

5. Conclusions

The morphological changes in cortical layer at the mandibular base (MCI) are related to the changes in calcaneal BMD, but the MCI accuracy is not sufficient for precise evaluation in screening of postmenopausal osteoporosis and is limited in clinical practice.

Conflict of interests

The authors state no conflict of interest.

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