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Mandibular bone mineral density measured using dual-energy X-ray absorptiometry: relationship to hip bone mineral density and quantitative ultrasound at calcaneus and hand phalanges

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Abstract. The main aim of this cross-sectional study was the estimation of relationships between mandibular bone mineral density (m-BMD), hip bone mineral densities (BMDs) and quantitative ultrasound at calcaneus and hand phalanges. Correlations between m-BMD and age, years since menopause (YSM) and body size were also evaluated. 42 edentulous persons (36 females and 6 males aged 60.5 ± 6.9 years) were evaluated. In the group studied no factors affecting bone metabolism (either medical conditions or medications) were noted. Bone status was assessed by dual-energy X-ray absorptiometry (mandible, hip—Lunar DPX-L), and quantitative ultrasound (calcaneus—Lunar Achilles which measures speed of sound (SOS, m s^{-1}) and broadband ultrasound attenuation (BUA, dB MHz^{-1}); and phalanges of the hand—DBM Sonic 1200 which measures amplitude-dependent speed of sound (AD-SOS, m s^{-1})). CV% for mandibular measurements was 2.06%. m-BMD correlated significantly with the following measurements: femoral neck $r=0.39$, $p<0.01$; Ward's $r=0.39$, $p<0.01$; calcaneal BUA $r=0.39$, $p<0.01$; and phalangeal AD-SOS $r=0.4$, $p<0.01$. Negative correlation consistent with a significant decrease with age was observed in m-BMD ($r=-0.36$, $p<0.05$) and AD-SOS ($r=-0.4$, $p<0.01$). BMD in the mandible also decreased with YSM ($r=-0.47$, $p<0.01$). m-BMD was correlated with age, YSM, height and weight in stepwise, multiple, linear regression analysis. The following equation was obtained: m-BMD $= -2.21 + 0.018 \times$ height (cm) $- 0.02 \times$ YSM (years) $+ 0.13 \times$ age (years). It may be concluded that mandibular BMD may be an appropriate measurement site for the evaluation of skeletal status in osteoporosis.

Osteoporosis is a systemic disease leading to increased fracture risk owing to deterioration in microarchitecture of bone tissue and low bone mass [1]. Fractures associated with osteoporosis occur commonly at sites such as the forearm, vertebrae or hip [2]. These parts of the skeleton are also popular sites for bone mineral density (BMD) measurements. The earliest suggestion of an association between osteoporosis and oral bone loss was made in 1960 [3]. In some more recent studies, authors have found correlations between mandibular bone mineral density (m-BMD) and BMD at other skeletal sites assessed by quantitative computed tomography (QCT) [4, 5], dual-energy photon absorptiometry (DPA) or single-energy photon absorptiometry (SPA) [6] and dual-energy X-ray absorptiometry (DXA) [7, 8].

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Hildebolt, in a recent review of the literature on the possible association between osteoporosis and oral bone loss, stated that although not all studies found associations between osteoporosis and oral bone loss, this association exists [9]. The relationships between generalized, involutional osteoporosis and local processes within the mandible should be studied longitudinally and inexpensive methods must be developed for sensitive and specific measures of oral bone loss.

In the current study the hypothesis that m-BMD may predict skeletal status in other parts of the skeleton was evaluated. To our knowledge, no comparison between m-BMD and quantitative ultrasound measurements at other skeletal sites have been published.

Subjects and methods

42 edentulous persons (36 females and 6 males) were evaluated. Some were patients referred to the Prosthodontic Department for complete denture construction, and the rest were volunteers

recruited after announcements in local newspapers. The study group was created from a total of 70 persons, of which 28 were excluded because of medical reasons known to affect bone metabolism (either medical conditions or medications). None of the subjects was on hormone replacement therapy or taking calcitonin, bisphosphonates or fluorides, except low doses of calcium or vitamin D. Each woman had a natural menopause. No past fractures were noted. Clinical characteristics of the study group are given in Table 1. The study was approved by a local ethics committee and informed consent was obtained from all persons.

Skeletal status was assessed by DXA and quantitative ultrasound (QUS). The following bones were measured: mandible (DXA—Lunar DPX-L, USA), hip (DXA—Lunar DPX-L, USA), calcaneus (QUS—Lunar Achilles, USA) and proximal phalanges of the hand (QUS—DBM Sonic 1200, Igea, Italy). Mandibular bone mass measurements were performed in the body of the mandible according to the methodology proposed by Horner et al [8]. All DXA measurements were done by the same operator. The CV% for mandibular measurements calculated on the basis of 15 measurements in five persons (four women and one man) was 2.06%. The individuals were randomly selected from edentulous patients evaluated in the study. Each measurement taken for the calculation of the precision was performed with repositioning and standing up between scans. BMD values taken for calculation of the precision are shown in Table 2. CV% for hip measurements was 2.5%.

Ultrasound measurements of the calcaneus using Achilles (Lunar, USA) were performed at the right (dominant) heel. Speed of sound (SOS (m s^{-1})) and broadband ultrasound attenuation (BUA (dB MHz^{-1})) were measured. All measurements were performed by the same operator. Short-term *in vivo* precision in women was established on the basis of 100 measurements on 20 healthy women (five for each of them). The CV% values were: SOS, 0.22%; BUA, 1.8%. Short-term *in vivo* precision in men was calculated on the basis of 60 measurements on 12 healthy men (five for each of them). The CV% values were: SOS, 0.33%; BUA, 2.48%.

Table 2. Mandibular body bone mineral densities taken for calculation of precision

	Bone mineral density (g cm^{-2})		
Woman 1	1.358	1.348	1.362
Woman 2	1.453	1.512	1.452
Woman 3	1.353	1.418	1.350
Woman 4	0.946	0.950	0.938
Man	1.608	1.647	1.584

Phalangeal ultrasound measurements were obtained using DBM Sonic 1200 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 μs. The receiver probe is positioned on the lateral side of the phalanx and obtains the ultrasound that has crossed the phalanx. The time interval between emission and reception of the ultrasound signal was measured and expressed in m s^{-1}. We determined the SOS in the distal metaphyses of the proximal phalanges of the second through fifth digits of the right hand. SOS in bone was calculated using the first signal with an amplitude more than 36 pixels on the screen. Thus the measured SOS was dependent on signal amplitude (amplitude-dependent speed of sound, AD-SOS). Acoustic coupling was achieved using a standard ultrasound gel. All measurements were undertaken by the same operator. *In vivo* short-term precision was based on mean coefficients of variation for 75 measurements on each of 15 healthy persons (8 males and 7 females) by the same operator. CV% was 0.64%.

Statistics

Means and standard deviations as well as simple and multiple linear regression analyses were calculated using the Statistica program run on an IBM computer. Correlations between variables studied were established using Pearson's coefficient of correlations.

Table 1. Clinical characteristics of study group

	Whole group (n=42)	Males (n=6)	Females (n=36)
Age (years)	60.4±6.9	60.7±7.4	60.4±6.9
YSM (years)	—	—	11.7±8.0
Weight (kg)	72.6±13.2	86.5±6.7	70.3±12.6
Height (cm)	159.3±7.8	170.8±5.5	157.4±6.3
BMI (kg m^{-2})	28.5±4.4	29.7±2.2	28.4±4.6

YSM, years since menopause; BMI, body mass index.

Table 3. Bone mineral densities and ultrasound values of study group

	BMD mandible (g cm^{-2})	BMD femoral neck (g cm^{-2})	BMD Wards (g cm^{-2})	BMD Trochanter (g cm^{-2})	BUA (dB MHz^{-1})	SOS (m s^{-1})	AD-SOS (m s^{-1})
Whole group (n=42)	1.221±0.3	0.901±0.17	0.771±0.19	0.827±0.17	104.5±9.4	1512.1±25.3	1943.9±58.5
Men (n=6)	1.409±0.4	1.098±0.26	0.992±0.33	1.023±0.21	106.8±12.4	1514.2±26.5	1973.2±27.4
Women (n=36)	1.190±0.27	0.868±0.12	0.734±0.13	0.795±0.14	104.1±8.9	1511.7±25.5	1939.1±61.1

BMD, bone mineral density; BUA, broadband ultrasound attenuation; SOS, speed of sound; AD-SOS, amplitude-dependent speed of sound.

Results

Bone mass and ultrasound values are shown in Table 3. Results are given for the whole group and for men and women separately.

Bone measurement parameters were correlated between themselves and with age, weight and height. In the whole group m-BMD correlated significantly with several other measurements: femoral neck r=0.39, p<0.01; Ward's r=0.39, p<0.01; AD-SOS r=0.4, p<0.01; BUA r=0.39, p<0.01. Borderline significant relationship was noted for correlation between m-BMD with SOS (r=0.29, p=0.06). Negative correlation consistent with a significant decrease with age was observed in BMD in the mandible (r=−0.36, p<0.05, simple linear regression equation: m-BMD=2.16−0.0156 × age (years)) and AD-SOS (r=−0.4, p<0.01).

Years since menopause (YSM) influenced significantly m-BMD (r=−0.47, p<0.01, simple linear regression equation: m-BMD=1.38−0.0161 × YSM (years)), AD-SOS (r=−0.39, p<0.05), SOS (r=−0.44, p<0.05) and borderline significantly BUA (r=−0.36, p=0.07) and Ward's (r=−0.33, p=0.099). Simple linear regressions of m-BMD with age and YSM are shown in Figures 1 and 2. m-BMD correlated positively with height (r=0.47, p<0.01). Height also correlated with all three hip measurements (r ranged from 0.53 to 0.59, p<0.01). Weight only influenced significantly the hip measurements (r ranged from 0.55 to 0.65, p<0.001) and BUA (r=0.32, p<0.05).

Correlations noted separately for females were similar to those obtained for the whole group; slightly stronger correlations were noted between m-BMD and Ward's (r=0.45, p<0.01) and BUA (r=0.5, p<0.01). The age-dependent decrease in m-BMD (r=−0.37, p<0.05) was almost the same as for the whole group (r=−0.36, p<0.05). m-BMD was also regressed on age, YSM, height and weight in stepwise, multiple, linear regression analysis and the following equation was obtained:

$$\text{m-BMD} = -2.21 + 0.018 \times \text{height(cm)} - 0.02 \times \text{YSM(years)} + 0.13 \times \text{age(years)}$$

Correlations for men are not shown because of the small number studied.

Discussion

There is growing evidence that after menopause some women experience an accelerated rate of alveolar bone loss [9]. It has been suggested that periodontal bone loss does not occur at equal

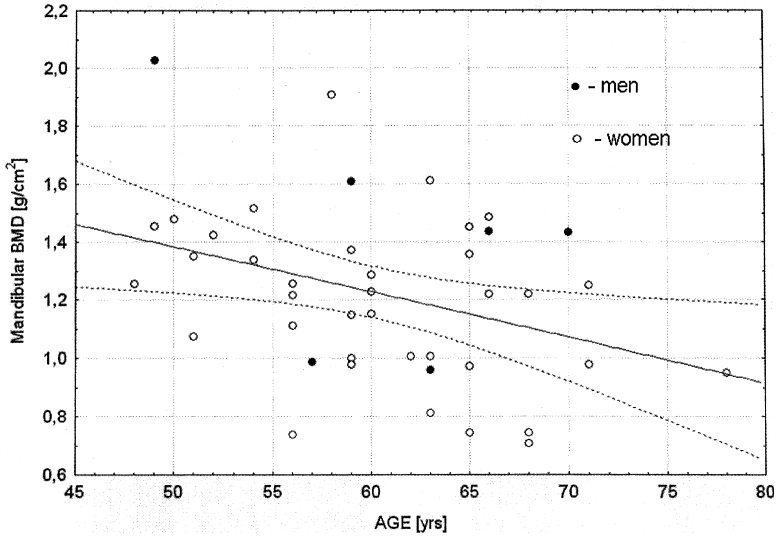

Figure 1. Simple linear regression between mandibular bone mineral density (BMD) and age.

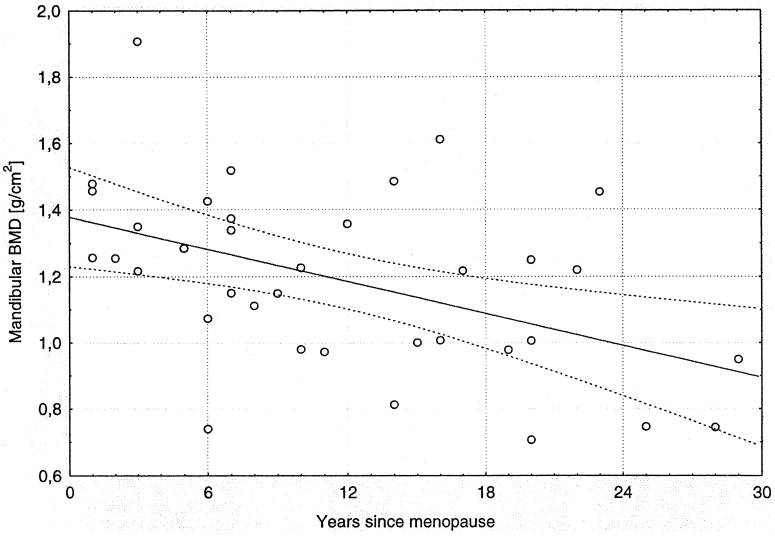

Figure 2. Simple linear regression between mandibular bone mineral density (BMD) and years since menopause.

rates throughout the population and the highest prevalences of loss occur in specific groups [10]. For many years it was assumed that local factors, such as the continuous wearing of ill-fitting dentures, were the sole cause of alveolar bone resorption [7]. Now it is accepted that there is a relation between alveolar bone loss in edentulous patients and metabolic disease [7], but it appears that significant correlations with other skeletal sites are obtained when more sophisticated analysis of the mandible, such as QCT or DXA, is used. There are several published studies where DXA [7, 8], QCT [4, 5] or older techniques such as SPA or DPA [6] were used to compare mandible with various bones. Kribbs et al [6, 11, 12] have found a significant correlation of mandibular bone mass with bone mass in the spine and forearm. Also, Horner et al [8] have found correlations with BMD in the mandible measured by DXA and BMD in the proximal and distal radius, lumbar vertebrae and the femoral neck. However, in the study by Von Wowern et al [13] on relationships between mandibular bone mineral content and spine no correlations were noted.

The results of the current study can be compared with those of Horner et al [8], who also used DXA for measurements of the mandible. In our study the methodology for mandibular bone mass measurements proposed by Horner et al was used. The similarity in mean age and age range facilitates this comparison. The population assessed in the study of Horner et al was slightly older than our population (65 *vs* 60 years), but the BMDs were close (1.1 *vs* 1.2 g cm^{-2}). The observed range in m-BMD was similar. A comparison of BMD for femoral neck in both female populations shows good agreement (mean 0.831 g cm^{-2}, range 0.61–1.17 g cm^{-2} in the study by Horner et al and mean 0.87 g cm^{-2}, range 0.65–1.07 g cm^{-2} in our study). In both studies, significant correlations with BMD at other skeletal sites were found, but the correlations were stronger in the study by Horner et al. For example, the correlation between BMD in the mandibular body and the femoral neck was 0.45 in the study by Horner et al and 0.39 in our study. No correlations with other hip measurements are given by Horner et al, so further, direct comparison is not possible. In our study, CV% (2.06%) was much better than in the other study. This good precision may be due to the experience of the technician who performed all the DXA measurements.

In this study we tried to correlate mandibular measurements with some quantitative ultrasound measurements. To our knowledge such an analysis has not been previously published. QUS at the calcaneus has been reported as a method for the estimation of fracture risk [14, 15] and the assessment of skeletal changes due to ageing or menopause duration [16, 17]. Recently, phalangeal ultrasound measurements have been developed, and at least one study proving longitudinally the ability to predict hip fracture risk has been published [18]. These measurements were also made to assess changes in the skeleton in children [19] and adults [20, 21]. In our study, we obtained significant correlations between mandibular BMD and phalangeal AD-SOS ($r=0.4$, $p<0.05$), calcaneal BUA ($r=0.39$, $p<0.05$) and borderline significance with calcaneal SOS ($r=0.29$, $p=0.06$). m-BMD also showed a similar age-dependent decrease ($r=-0.36$, $p<0.05$) to AD-SOS ($r=-0.4$, $p<0.05$). A slightly smaller age-dependent decrease was observed for calcaneal parameters ($r=-0.27$–0.28, $p<0.1$). Only the Ward's age-dependent decrease for women was significant ($r=-0.4$, $p<0.05$), while BMD for the trochanter and neck was stable.

In conclusion, precise mandibular bone mass measurement provides information that correlates

with BMDs and ultrasound parameters in other sites of the skeleton. These data suggest that this measurement may be a method of identifying persons affected by generalized osteoporosis. Longitudinal studies are warranted to estimate prospectively changes in the mandible and to compare this information with parallel changes in other skeletal sites. Despite the obvious limitations of the current study (cross-sectional study design and small numbers of cases), the results are promising. We plan to repeat all measurements after 2 years to detect longitudinal changes in measured bones.

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