RESEARCH

The relation between bone mineral density in the heel and pixel intensity in the mandibular jaw bone among elderly women

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Objectives: The purpose of this study was to investigate the correlation between pixel intensity (PI) in digital radiographs of the lower jaw and bone mineral density (BMD) in the heels of post-menopausal women (as measured with DXL, a combination of dual energy X-ray absorptiometry and lasers).

Methods: Two intraoral periapical digital radiographs were taken in the right and left mandible premolar region, and the digital images were analysed by a computer program (Dimaxis) regarding PI. As the radiographs were taken, the BMD of the patient's left heel was measured *via* a portable Calscan device. The patient answered a questionnaire concerning risk factors. The correlation between variables was analysed using statistical tests.

Results: A significant correlation was found between the PI in the left ($P = 0.001$) and right ($P = 0.004$) mandible and the BMD of the left heel for the whole group. A pronounced correlation was found to exist for women > 70 years old. Based on a cut-off value of the PI, to differentiate between healthy individuals and those who required further analysis for osteoporosis, the following values were obtained: sensitivity 0.74, specificity 0.50, positive predictive value 0.77 and negative predictive value 0.46.

Conclusion: A positive correlation was found between PI in digital radiographs of the mandible and the BMD of the heel. The low predictive value does not allow any definite conclusions to be drawn from the present study. A reasonable recommendation could be for future studies to employ a larger study population to explore the effect on this value.

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Introduction

Osteoporosis (OP) is a widespread problem that mainly affects women in the Western world. A fragility fracture, particularly in the hip, spine or forearms is usually the first sign of OP. In Sweden, every second woman will suffer from a fragility fracture during her lifetime.¹ OP is defined as a reduction in bone mass and disruption of bone architecture that results in reduced bone strength and increased fracture risk.² The diagnosis of OP is based on a measure of bone mineral density (BMD) in the hip or spine (gold standard) by dual energy X-ray absorptiometry (DXA). During the last decade, a new method has been developed for determining BMD, namely DXL, which combines DXA with lasers to determine the different absorptions

of bone mineral, adipose and lean soft tissues.³ When using the portable Calscan device for OP screening, an upper and a lower triage threshold is applied, which classifies the study population into a group that in all probability has OP, a group that is unlikely to have OP and a group about which there is uncertainty and requires further analysis.⁴ This procedure, in which the screened population is divided into three groups, allows an individual with OP in the hip or spine to be identified with 90% sensitivity and 90% specificity.⁴

Because OP is such a widespread problem, there is an ongoing discussion of the benefit of a preventative screening. OP affects all of the bones in the human body, including the mandible. The BMD in the mandible, measured with DXA, has been shown to correlate with the BMD in other skeletal sites, such as the spine, femoral neck, forearm, hip and heel.^{5,6} Recent studies have shown that DXL heel measurements are able to

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diagnose OP occurring at the femoral neck or lumbar spine with a sensitivity of 75–80% and a specificity of 73–82%.^{7,8}

As most people visit the dentist regularly, dental visits would be a perfect situation to screen for OP. Within odontology, different methods have been used over the last decade to detect OP in the jaw. Most studies focused on detecting OP have been performed using panoramic images that measure the mandible cortical width,^{9–11} or study pixel intensity (PI).¹² Some authors have also studied periapical radiographs. Law *et al.*¹³ analysed PI in analogue radiographs that had been scanned into a computer. Jonasson *et al.*¹⁴ studied the trabeculation in analogue apical radiographs from the premolar region, and showed that sparse trabeculation was correlated with a low BMD. In a later study, Jonasson *et al.*¹⁵ digitized these analogue radiographs in order to measure the density of the interdental alveolar bone mass, and found that the mean alveolar bone mass (expressed as a grey-level value) was correlated with BMD in women, but not in men. In the OSTEODENT project, Lindh *et al.*¹⁶ stated that visual assessment of trabeculation could be a method of finding patients with OP. Recently, digital X-ray equipment has become more common in dental practices, and digital images can be analysed on the computer, in a simple and objective method, *e.g.* for measurements of PI.

The objective of this study was to study the correlation between PI in digital periapical radiographs of the lower jaw and BMD in the heel among postmenopausal women.

Materials and methods

Participants

All 215 post-menopausal women (60–74 years old) attending the public dental services in Varberg during 2004 were invited to participate in this cross-sectional, operator-blinded clinical study, which was conducted at the same time as their regular check-up. Of the invited women, 33 were excluded because they did not have teeth in the premolar region, because they had solid exostosis or because they simply were not interested in participating. The included women ($n = 182$) were informed verbally and in writing about the survey, and a written consent was obtained from all the participants. The Ethical Committee of Gothenburg University, Sweden, approved the study.

Dental radiograph examination

At the patients' regular check-up visits at the Public Dental Services, Varberg, two intraoral periapical digital radiographs were taken in the right and left premolar region, according to the method defined by Jonasson *et al.*¹⁴ All digital pictures were taken with the same apparatus, a Gendex 765 DC (Gendex, Milwaukee, WI),

at 60 kVp, 7 mA, and with the same exposure time (0.8 s). The procedure was performed by the same dental nurse in the following standardized manner. The long cone was placed in contact with the cheek, and the sensor was placed close to the lingual border of the lower jaw, using a parallel technique. The digital radiographic pictures were stored in an X-ray program, Dimaxis (Plandent, Helsinki, Finland). The radiographic pictures were examined by the same dental surgeon (LH) at the same computer. All data, except for the age of the participating patients, were unknown to LH until the project was finished. In a digital image (using an 8 bit system), each small square area (a pixel) has a grey value between 0 and 255. 0 corresponds to totally black, and 255 to totally white. This numeric value is called the PI. The analysis of the periapical digital radiographs was made as follows: a region of interest (ROI), with a standardized area of 1 cm², was selected between the apical part of the premolars on the right and left side of the lower jaw.¹⁴ Cases exhibiting a deviant anatomical structure (*e.g.* foramen mentale) were excluded. The selected area, which consisted of approximately 6000 pixels, was automatically analysed by the Dimaxis X-ray program, thus producing a PI (mean and standard deviation) for each ROI. Radiographs of 30 patients (18%) were chosen randomly for an additional measurement of the PI value to obtain a measure of intraobserver agreement.

Heel BMD and risk factors

After the dental examination, the dental nurse measured the BMD in the patient's left heel. The BMD was measured using a portable Calscan DXL device (Demetech, Täby, Sweden). The recommended upper and lower triage T scores for this device are 1.4 SD and 2.7 SD.⁴ The patient completed a standardized questionnaire pertaining to risk factors. The questionnaire included the following risk factors: height reduction > 3 cm before or > 5 cm after the age of 70 years, BMI < 20, weight loss equals present weight ≥ 10 kg below the weight at the age of 25, previous fragility fracture, menopause before 45 years of age, glucocorticoid medication used for > 3 months, current daily smoking or a previous history of smoking ≥ 10 year period and hip fracture among parents. All information was stored in a data program connected to the Calscan DXL apparatus. The risk factor questionnaire and the result from the DXL heel examination were sent to one of the authors (HB) for analysis and for medical advice.

Statistical methods

In addition to descriptive statistics, Student's *t*-test and Pearson correlation were used for continuous, normally distributed variables. The Mann–Whitney *U*-test and Spearman's correlation were employed for variables with a skewed distribution. The Cohen kappa index was used to determine intraobserver agreement. All statistical tests were two-tailed. The significance level was set at 0.05.

Table 1 Presentation and comparison of age, pixel intensity (PI) and bone mineral density (BMD) between the different age groups (mean values, interquartile ranges (IQRs) and *P*-values)

	Age group 60–64 (n = 64)		Age group 65–69 (n = 70)		<i>P</i> *	Age group 70–74 (n = 48)		<i>P</i> †	<i>P</i> **	Age group 60–74 (n = 182)	
	Median	IQR	Median	IQR		Median	IQR			Mean	SD
Age (years)	61.0	60.0–63.0	67.0	66.0–68.0	<0.0001	72.0	71.0–73.0	<0.0001	<0.0001	66.5	4.3
PI	88.6	79.0–107.0	89.6	76.6–105.6	0.737	86.2	73.9–100.5	0.218	0.308	89.6	21.5
BMD	0.39	0.36–0.44	0.38	0.33–0.42	0.167	0.35	0.28–0.39	<0.0001	0.004	0.37	0.07

Comparison between the first and second age group*, the first and third†, the second and third**

Results

The mean age of the study groups is presented in Table 1. The prevalence of a fragility fracture was 12.5% in the youngest age group, 20.0% in the middle age group and 25.0% in the oldest group. 42% were daily smokers, 21% had a parent with a hip fracture, 19% had used glucocorticoid medication > 3 months and 16% had an abnormal loss of height. The PI and BMD values for the different age groups are presented in Table 1. The 70–74 age group had a significantly lower BMD value than the 60–64 ($P < 0.0001$) and 65–69 age groups ($P = 0.004$). For the whole group (including the 60–74 year olds), the measurements concerning the mandible and heel were significantly correlated for both the left ($r = 0.25$, $P = 0.001$) and right side ($r = 0.21$, $P = 0.004$)

(Table 2). The correlation between BMD and the PI value was strongest in the oldest age group ($r = 0.46$, $P = 0.001$) (Table 2). The pixel value between the left and right mandible was strongly correlated ($r = 0.60$ – 0.82 , $P < 0.0001$) (Table 2). The PI value intraobserver agreement was 0.93 ($P < 0.0001$). Table 3 illustrates how individuals were distributed between a cut-off value that differentiated between those who were healthy and those who required further tests. The cut-off value of heel DXA was -1.4 SD and the PI value was 100. The number of individuals considered unaffected by OP on the basis of the cut-off value for heel DXA was 31% (56/182), which increased to 34% (61/182) when estimated by the PI method. Based on the values in Table 3, the sensitivity was 0.74, specificity 0.50, positive predictive value 0.77 and negative predictive value 0.46.

Table 2 The correlation between bone mineral density (BMD) and pixel intensity (PI) in left and right mandible in different age strata, as calculated by Spearman correlations

		BMD	PI in the left mandible	PI in the right mandible
<i>Age 60–64 years (n = 64)</i>				
BMD	<i>r</i>	1	0.184	0.099
	<i>P</i> -value		0.145	0.434
PI in the left mandible	<i>r</i>		1	0.824
	<i>P</i> -value			<0.0001
PI in the right mandible	<i>r</i>			1
	<i>P</i> -value			
<i>Age 65–69 years (n = 70)</i>				
BMD	<i>r</i>	1	0.163	0.108
	<i>P</i> -value		0.178	0.374
PI in the left mandible	<i>r</i>		1	0.601
	<i>P</i> -value			<0.0001
PI in the right mandible	<i>r</i>			1
	<i>P</i> -value			
<i>Age 70–74 years (n = 48)</i>				
BMD	<i>r</i>	1	0.459	0.282
	<i>P</i> -value		0.001	0.052
PI in the left mandible	<i>r</i>		1	0.711
	<i>P</i> -value			<0.0001
PI in the right mandible	<i>r</i>			1
	<i>P</i> -value			
<i>Age 60–74 years (n = 182)</i>				
BMD	<i>r</i>	1	0.252	0.214
	<i>P</i> -value		0.001	0.004
PI in the left mandible	<i>r</i>		1	0.709
	<i>P</i> -value			<0.0001
PI in the right mandible	<i>r</i>			1
	<i>P</i> -value			

Pearson correlations were used for the whole group (60–74 years)

Table 3 The distribution of the study population on the basis of a cut-off value of -1.4 standard deviation (SD) of the dual energy X-ray absorptiometry (DXA) and 100 of the pixel intensity (PI) method

	<i>DXA ≤ -1.4 SD pathological value (n)</i>	<i>DXA > -1.4 SD normal value (n)</i>	<i>Total (n)</i>
PI method < 100 pathological value (<i>n</i>)	93	28	121
PI method ≥ 100 normal value (<i>n</i>)	33	28	61
Total (<i>n</i>)	126	56	182

Discussion

In this study, a positive correlation was found between BMD in the heel and the PI value in digital periapical radiographs from the left and right mandible. As no other study has used the PI from digital radiographs, it is difficult to compare our results with those from other studies. In a few surveys, the PI was analysed after analogue radiographs were scanned into a computer. In one study, a positive significant correlation was found between a low PI value of the intraoral radiographs and OP in women,¹³ but this conclusion can be questioned as the OP group was much older than the controls, something that was not compensated for. In another study among peri- and post-menopausal women, a significantly lower PI (obtained by digital panoramic imaging) in the osteoporotic group than in the normal group was found, but the sensitivity for detecting OP was low.¹² A positive significant correlation between BMD in the forearm and the grey-level value in digitized intraoral periapical radiographs was found among women, but not among men.¹⁵

The PI method can be used in clinical screening to identify individuals who in all probability are healthy and those who require further medical investigation, either because they are most likely to be affected by OP or because they belong to the group about whom we are uncertain and therefore need to be investigated further. If the PI method were to be used for such screening, it would mean that, out of the 100 individuals who, according to heel DXA, require referral to the health care system, only 74 would be identified.

Out of 100 individuals who, according to the PI method, would need to be referred to the health care service, heel DXA would yield the same result in 77 individuals but the remaining 23 individuals would constitute a false positive.

Of 100 individuals who, according to the PI method, have healthy bones, 54 would be recommended for further investigation by the heel DXA method.

The PI method would be quite useful for identifying those who require referral to the health care service in this age group, but it would also lead to too many individuals being falsely declared healthy. The correlation between PI in the mandible and BMD was strongest in the 70–74 year age group. The significance disappeared for the younger age groups, probably partly because the group was too small, but also because of a weaker correlation. Furthermore, the age-related loss of BMD of the skeleton seems to be greater in the mandible than in the hip and heel.¹⁷ These

findings indicate that the use of PI in the mandible as a screening to identify individuals with a low bone mass is probably more appropriate for individuals who are over 70 years old. However, the data in the present study are insufficient for establishing whether or not this is the case.

Methodological aspects

The radiograph is a summary of all structures passed by the X-ray beam. The thickness of the cheek and the mandible corticalis may thus have an effect on the PI value. In older women, especially those of low weight, thinning of the bone and the cheeks would be expected, thus giving a lower PI value. The value of intraobserver agreement demonstrated the high precision of the method. Placing a small metal piece (as a reference) on the digital sensor would be a better method for obtaining more comparable values with different types of radiographic apparatus. BMD was measured in the left heel because it is most often the non-dominant side. This choice was based on the knowledge that there is no difference in BMD between the left and right side.^{18,19} This finding is not unambiguous, as later surveys have found a higher BMD value in the non-dominant heel.^{8,20}

In conclusion in post-menopausal women over 60 years of age, a positive correlation between BMD in the heel measured with DXL and the PI obtained from digital intraoral periapical images of the mandible was found. This correlation was more pronounced in the 70–74 year age group. The low predictive value does not allow any definite conclusions to be drawn from the present study. A reasonable recommendation would be for future studies to have a larger study population in order to explore the effect on this value.

They should also focus on women > 70 years old and correlate mandible density data with the occurrence of fractures.

The result of this study indicates a positive correlation between the PI in the mandible and BMD in the heel, but, despite the fact that the sensitivity is acceptable (0.74), the negative predictive value of 0.46 contributes to the inability to draw any firm conclusions in this regard, as it is too low to be used as a screening method. Further development is required before it can be used as a screening method for OP.

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