RĪGA STRADIŅŠ UNIVERSITY

ANDA SLAIDINA

The impact of osteoporosis on the structures of oral cavity in postmenopausal

(speciality – prosthodontics)

Summary of the Promotion Paper

Scientific supervisors:
Doctor of Medical Science, Associated Professor **UNA SOBOLEVA**

Doctor of Medical Science, Professor **AIVARS LEJNIEKS**

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The promotion work was performed in the Department of Prosthodontics of Rīga Stradiņš University

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The Promotion Paper is available at the library of Rīga Stradiņš University.

Secretary of the Promotion Council:

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1 INTRODUCTION

Osteoporosis is a systemic disease characterized by decreased bone density, impaired microachitecture leading to the loss of bone strength and consequent increase of bone fracture risk (Peck et al. 1993; NIH 2001). It is very common disease among population in moderate climate zone around the world, and it is directly connected with age. According to the data of the World Health Organisation osteoporosis is the second most common disorder following cardiovascular diseases (WHO, 1994), and fractures caused by it are observed in every third female and every fifth male older than 50 years (Melton, 1992). Although this disease is observed among females and males, the most common type in 90% of cases is postmenopausal osteoporosis (Albright, 1941). Experts estimated that in Latvia 160 000 – 200 000 females in age group 45- 80 years may have osteopenia or osteoporosis (Lejnieks, 2005).

Osteoporotic fractures frequently are causing disability with significant decrease of the quality of life or even death (Melton, 1993). Therefore, timely diagnosis, prevention or start of treatment of osteoporosis is becoming very important. However, diagnostic method nowadays most commonly used - dual energy X-ray absorptiometry (DEXA) – is not available for majority of population and can not be used as a screening method (Kanis, 1994). Currently various questionnaires are used in order to estimate the risk of osteoporosis and refer patient to DEXA, and its accuracy significantly differs in various populations (Cadareette, 2000). Since postmenopausal women often visit dentist, where one of the primary examination is orthopantomogram x-ray images (OrtPG), the following hypothesis was raised – dental x-ray images may be used for assessment of the risk of osteoporosis (Ledgerton, 1999; Klemetti, 1994).

There is an opinion that females with reduced bone mineral density have a higher rate of tooth loss. However, research findings are controversial (Taguchi, 1999; Inagaki, 2001; Kribbs, 1989; Earnshaw, 1998). Since the rate of tooth lose among Latvian population is higher than European average this issue becomes very important (Soboleva, 2006; Care, 2007).

Loss of teeth leads to the resorption of alveolar bone, which is chronic progressive and irreversible process which is not yet completely understood. There are several factors related to the jawbone resorption – anatomical, metabolic, mechanical and prosthetic (Atwood, 1971). Some researchers think that metabolic factors, such as

osteoporosis, are very important in the development of jawbone resorption (Atwood, 2001; von Wowern, 2001). However, findings of studies on impact of osteoporosis on jawbone resorption are controversial (Kribbs, 1989; Kribbs, 1990a; von Wowern and Kollerup, 1992; Bollen, 2004).

2 THE AIM AND TASKS OF THE DOCTORAL THESIS

Aim

To assess the impact of osteoporosis on jaw bones, alveolar bone resorption and loss of teeth of postmenopausal women.

Tasks

1) To evaluate whether or not mandibular bone x-ray structure and thickness in menopausal women are affected by:
    - overall bone mineral density;
    - body mass index (BMI), height and weight;
    - use of removable dentures.
2) To evaluate the use of orthopantomogram x-ray images (OrtPG) for identification of reduced bone mineral density in postmenopausal women.
3) To assess whether or not reduced bone mineral density in postmenopausal women affect loss of teeth:
    A. To assess the relationship between bone mineral density and:
    - total number of teeth lost;
    - number of front teeth and posterior teeth;
    - number of teeth in maxilla and mandible.

    B. To assess whether or not bone mineral density is lower in females with edentulous jaws than is females with complete set of teeth.
4) To assess whether alveolar bone resorption in edentulous females is affected by:
    - overall bone mineral density;
    - body mass index, height and weight.

3 MATERIAL AND METHODS

The study population included patients aged 45-84 years from the Prosthetic Clinic of the RSU Institute of Stomatology, who attended clinic during the time period April 2007 - October 2009. Patients were included upon they agreement to participate, which was recorded in the consent protocol. The study was approved by RSU Ethics Committee.

Patients with diseases and conditions leading to secondary osteoporosis (renal diseases, hyperparathyroidism, Cushing's syndrome, thyrotoxicosis, rheumatoid arthritis, organ transplantation, diabetes etc.) and females with early menopause (before age of 45) or menopause caused by surgery were excluded from the participation in the study. Women currently or one year before start of the study taking medicines affecting bone metabolism (glucocorticoids, biposphonates, strontium renelate, selective estrogen receptor modulators, HRT, calcitonin, active vitamin D metabolites, teriparatide etc.), except calcium taken less than 1000 mg/day and vitamin D taken less than 800 IU/day, were also excluded from the participation in the study. Smokers and alcohol abusers (more than 14 alcohol units per week) also were excluded from the participation in the study.

According tot the aim of the study following examinations was performed:

1) Clinical examination of the oral cavity, loss of teeth, presence of dentures;

2) Dual energy X-ray absorptiometry (DEXA) (Lunar DEXA DPX-NT, GE Medical Systems – Riga Hospital No 2). This examination was performed for lumbar vertebra (*L2-L4*) and both hips *(total hip mean)*. All examinations were performed by one experienced professional (Dr. Ilze Daukste). The worst T- score reading (L2-L4 and total hip mean) was taken into consideration. Patients were divided into 3 groups according to the WHO criteria: normal bone mineral density (*T-score +2,5 to -1*), osteopenia (*T-score <-1,0 to -2,5)*, osteoporosis (*T-score* $\leq$ *-2,5)* (WHO, 1994). Height and weight were measured prior DEXA examination. Body mass index (BMI) was calculated dividing body mass in kilos by square height in meters (BMI= kg/m^2);

3) Digital orthopantomogram x-ray images OrtPG (*Pantomograph Trophypan C*- RSU Institute of Stomatology*)*, with one standard position. Images were taken using amperage 10mA and intensity range 60-90 kV, exposition time 15 s. All images were taken by one experienced assistant radiologist (Vineta Klavina). Magnification of the x-ray image was 1.27 and there was no adjustment for it.

3.1 The impact of osteoporosis on x-ray indices of jawbone among postmenopausal women

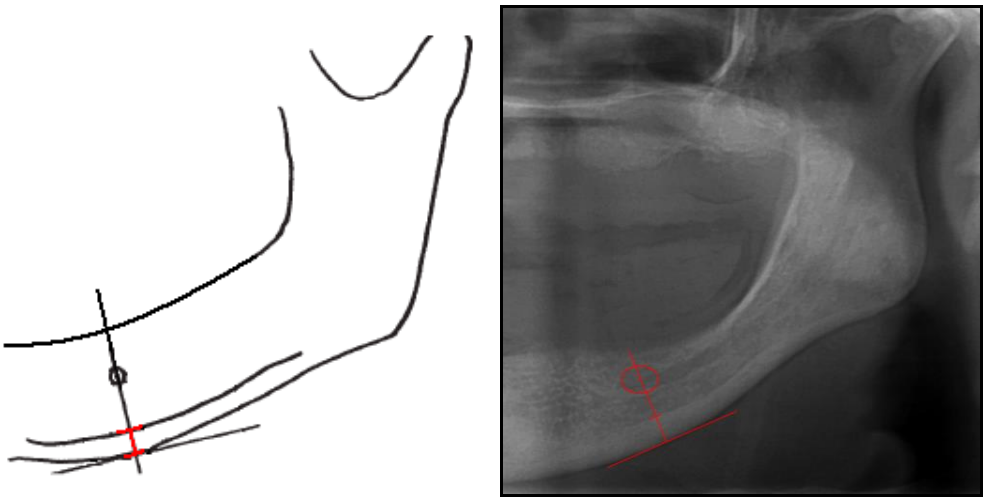
The study population included 131 postmenopausal woman aged 49-81 (mean age 64.97±9.18) who attended Prosthetic Clinic of the Rīga Stradiņš university Institute of Stomatology during the time period February 2009- October 2009.

Patients undergo DEXA and digital orthopantomogram (OrtPG) examinations.

According to the findings of DEXA patients were dividend into three groups – normal bone mineral density, osteopenia, osteoporosis. Digital x-rays were used to estimate Mental Index (MI) (Ledgerton, 1999) and Mandibular Cortical Index (C) (Klemetti,1994b) by means of computer programme (*Trophy Windows 6,04)*.

Mental Index is the cortical thickness in millimetres at the mandibular mental foramen area. It was measured by drawing the line perpendicular to the bottom of the mandible at the middle of the mental foramen. Cortical thickness was measured on this line at the both sides of mandibula (Figure 1). When it was not possible to obtain accurate measurement for both sides, only one side measurement was taken.

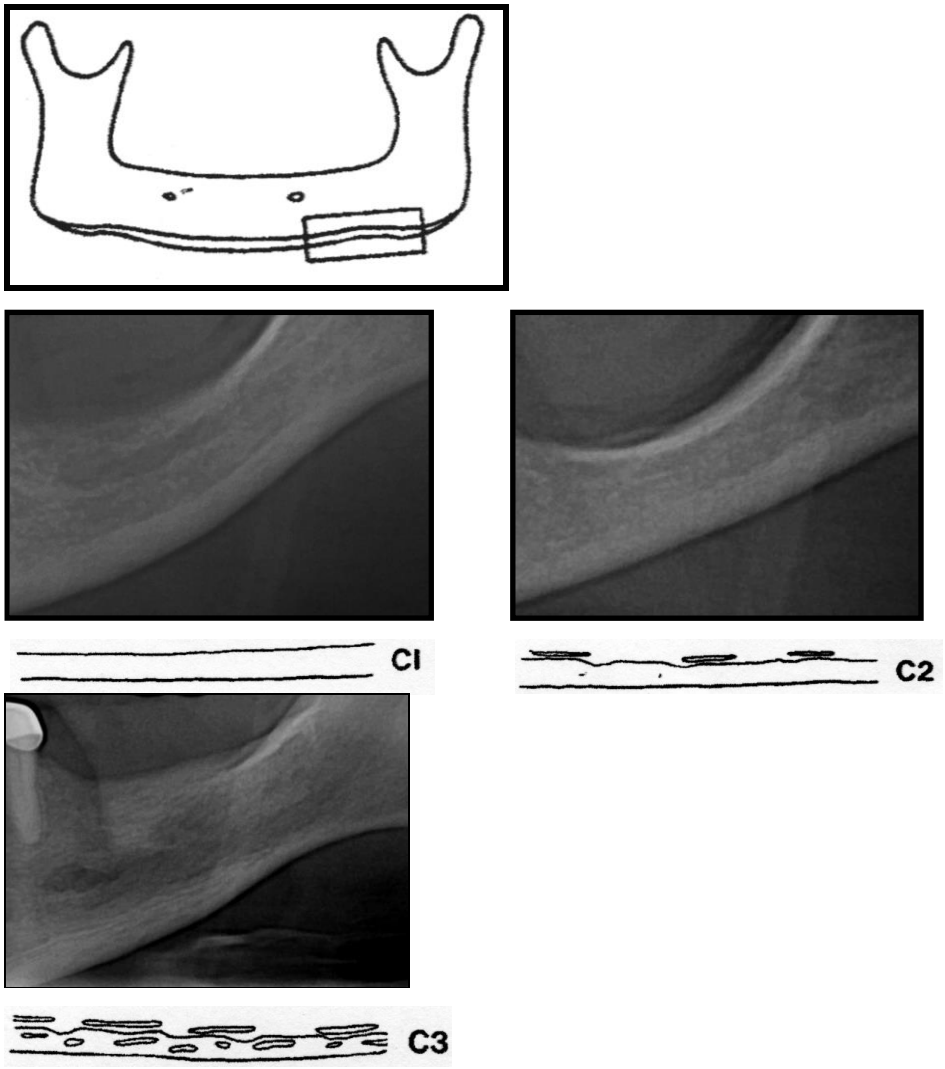
Figure 1



Schematic and x-ray reproduction of Mental Index (MI) (Ledgerton,1999, Slaidina, 2008)

Mandibular Cortical Index describe x-ray structure of mandibular cortical bone, and it is measured at both sides of mandibula distal from the mental foramen. Three severity grades were determined by using Klemetti classification – C1 - endosteal margin of the mandibular cortex was even and sharp at both sides of mandibula; C2 – endosteal margin with semilunar defects and cortical residules at one or both sides of mandibula; and C3 – deep endosteal residules and presence of porosity (Klemetti,1994b) (Figure 2).

Figure 2



Schematic and x-ray reproduction of Cortical Index (MI) (Klemetti, 1994b; Slaidina, 2008)

In order to evaluate reproducibility of the measurements, all measurements were performed according to the description of method by 3 people, one was experienced professional, second was physician dealing with this kind of x-ray images (OrtPG) in

everyday life, and the third was student, who used x-ray images rarely. Each observer performed 2 measurements with 2 week interval between measurements.

3.1.1. The impact of the use of removable dentures on x-ray indices of jawbone

The study population included 84 postmenopausal women aged 51-80 (mean age 66.71±7.68). Study population included 42 women from previously described study group with complete dentures made in RSU Institute of Stomatology that they were using for at least 2 years. All patients undergo DEXA examination and according to the findings of DEXA patients were dividend into three groups – normal bone mineral density, osteopenia, osteoporosis. Group of controls included patients with retained teeth in premolar area and no removable mandibular dentures, and it was matched by age and bone mineral density. Finally, there were 42 pairs of women with the same age and bone mineral density.

Patients undergo digital orthopantomogram (OrtPG) examination and these images were used to estimate Mental Index (MI) (Ledgerton,1999) and Mandibular Cortical Index (C) (Klemetti,1994b) by means of computer programme (*Trophy Windows 6,04)* (see above). All measurements and indexes were determined by one experienced observer.

3.2. Postmenopausal osteoporosis and loss of teeth

Study „A”

The study population included postmenopausal women with partial adentia, who attended the Prosthetic Clinic of the Riga Stradins University Institute of Stomatology during the time period February 2009- May 2009 agreed to participate and undergo all necessary examinations. In total 96 women were included in the study, 79 (82.29%) of which aged 49-81 (mean age 62,9 ± 9,23 years) and agreed to participate and undergo all necessary examinations.

For all patients bone mineral density was determined and DEXA was performed. DEXA indices for spine (L2-L4) and proximal femoral heads (hip mean) were used for analysis. Patients were dividend into 3 groups according tot the DEXA findings based on the WHO criteria. The number of present front teeth (incisors and canine teeth) and posterior teeth (premolars and molars) in mandibula and maxilla was

determined during clinical examination of the oral cavity. Implants, roots and retentive teeth were not included in calculation.

Women with complete tooth loss were not included in the study.

Study „B"

The study population included 98 postmenopausal women aged 50-81 (mean age 67.55±7.96 years).

The study population included 49 women from the A study with partial adentia (min. number of teeth was 6). Each patient had a matched pair – woman of the same age with edentulous jaws and complete dentures made in RSU Institute of Stomatology. In total there were 49 pairs of women with the same age and different level of teeth loss.

For all patients bone mineral density was determined by DEXA and clinical examination of the oral cavity was performed.

3.3. Osteoporosis and alveolar bone resorption of edentulous jaws in postmenopausal women

Study population included 50 postmenopausal women aged 51-84 (mean age 67.88±8.2 years) with edentulous jaws and complete dentures made in Prosthetic Clinic of the RSU Institute of Stomatology that they were using for at least 2 years.

According to the findings of DEXA patients were dividend into three groups – normal bone mineral density, osteopenia, osteoporosis.

Digital x-rays were used for different measurements in vertical plane by means of computer programme (Trophy Windows 6,04).

The line of reference *Lz* connecting lower ridges of *processus zygomaticus maxillae dx. et sin.* was drawn in maxilla. Measurements perpendicular to the line *Lz* up to alveolar ridge were performed:

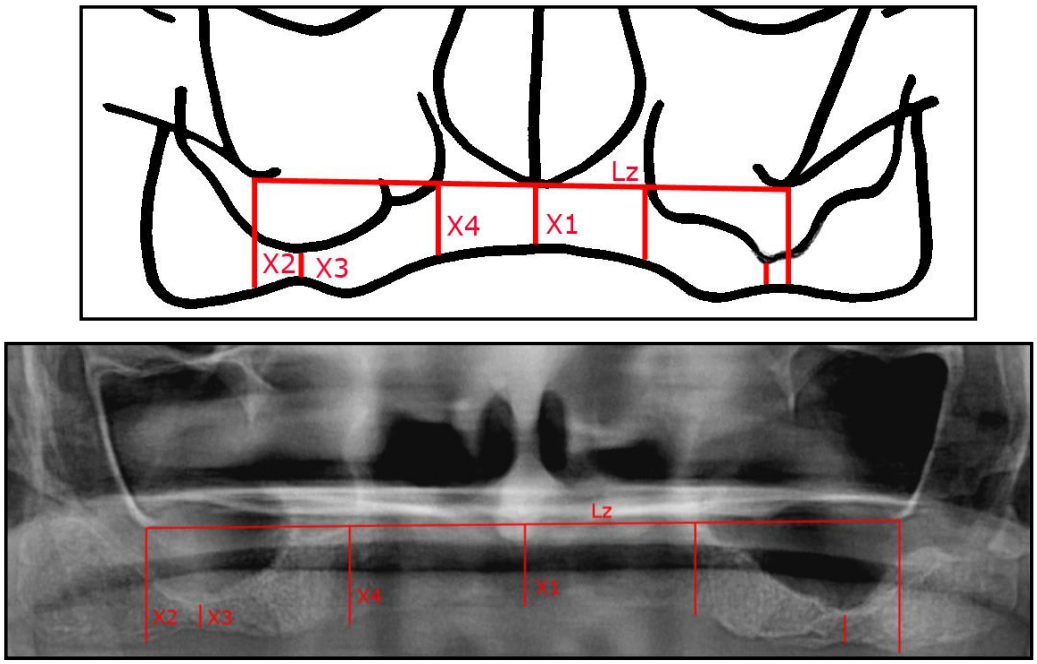
X1 – line trough maxilla centre line guided by nasal septum and *spina nasalis* (Guler, 2005);

X2 – distance from the lower point of *processus zygomaticus*;

X3 – distance from the lower point of *sinus maxillaris* (Guler, 2005);

X4 – from the *Lz* line in mesial direction along with the more pronounced curvature of *sinus maxillaris* (Figure 3).

Figure 3



Schematic and x-ray reproduction of maxillar measurements (Guler, 2005; Ozola, 2008)
Lz – line connecting lower margins of zygomatic bones at both sides;
X1 – distance on the perpendicular line to Lz line that is drown trough maxilla centre line up to alveolar ridge;
X2 – perpendicular line to Lz from lowest point on mental bone up to alveolar ridge;
X3 – distance on the perpendicular line to Lz line from the base of maxilla cavity up to alveolar ridge;
X4 – distance from Lz up to alveolar ridge along the anterior margin of maxilla cavity.

Two perpendicular lines were drawn on mandibula from lower to upper margin of bone against longitudinal axis of mandibula in two different areas, that are contact lines A and B in respective points:

Y1 – perpendicular line trough centre line (Guler, 2005);

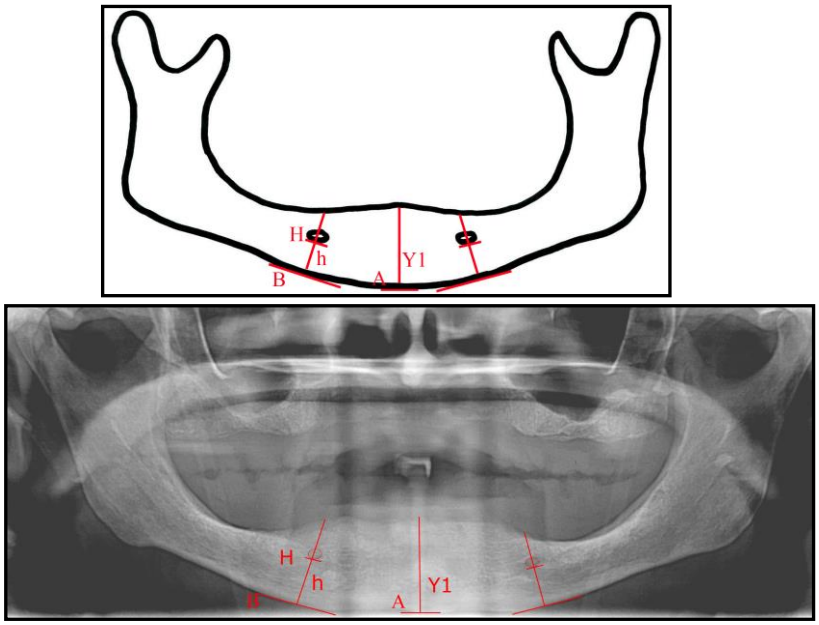
H – perpendicular line trough midpoint of foramen mentale (Wical and Swoope, 1974);

h – distance on this line from lower margin of mandibula up to lower margin of foramen mentale Wical and Swoope, 1974) (Figure 4).

Ratio of these measurements *H/h* labeled as MR index was calculated by method proposed by Wical and Swoope (Wical un Swoope, 1974).

In order to assess the measurement error all measurements were made and indexes determined by one observer twice with at least 2 week interval.

Figure 4



Schematic and x-ray reproduction of mandibular measurements (Wical un Swoope, 1974; Guler, 2005; Ozola, 2008)

A and B contact point against mandibular margin at centre line and mental foramen area;

H – distance from mandibular margin up to alveolar ridge in mental foramen area, which is perpendicular to contact point B;
h – distance on line H from mandibular margin up to lower margin of mental foramen;
Y1 – distance from mandibular margin up to alveolar ridge in centre line, which is perpendicular to the contact point A.

Statistical analysis

Distribution of values by different groups were determined using 2×2 and r×c frequency tables. Statistical significance of the proportion difference was assessed using Pearson χ square test. Statistical significance of mean difference was tested using t-test.

Pearson correlation and Spearman's rho correlation was used to determine correlation between different variables. Grouping of correlation coefficient was as follows: r = 0,8-1,0 very strong correlation; r = 0,5- 0,8 moderate; r = 0,2- 0,5 weak correlation; less than 0,2 insignificant correlation (Baltins, 2003). Percentage of variation or determination was calculated as $r^2 x100$.

ANOVA analysis of variance was used to determine relationship between different variables by group.

2x2 frequency tables were used to determine diagnostic test value of reduced bone mineral density expressed by Mental Index and Cortical Index. Sensitivity (how many cases of a disease a particular test can find) and specificity (how accurately it diagnoses a particular disease without giving false-positive results) of the method was calculated. Sensitivity of the test= a/ (a+c); Specificity of the test = d/(b+d), where

a- persons with true-positive result
b- persons with false-positive result
c- persons with false-negative result
d- persons with true-negative result (Baltins, 2003)

The intra- and interobserver agreement on Cortical Index was evaluated by means of Kappa coefficient (k). Where k>0,81 prominent agreement; 0,61-0,8 very good agreement; 0,41-0,6 good agreement; 0,21-0,4 moderate agreement; k<0,2 poor agreement (Landis un Koch, 1997) Measurement error for different observers was determined by using Dahlberg method, where value less than 1 was considered as accurate measurement (Dahlberg, 1940).

$$s(i) = \sqrt{\frac{\sum d^2}{2n}}$$

4 RESULTS

4.1. The impact of osteoporosis on x-ray indices of jawbone among postmenopausal women

According to the DEXA results all females were dividend into 3 groups: females with normal bone mineral density – 43 (mean age 63.33 ± 9.8 years), females with osteopenia -55 (mean age 64.6± 8.99 years), and females with osteoporosis - 33 (mean age 67.73 ± 8.27 years) (Table 1). The age differences between groups were not statistically significant (p=0.108).

Table 1

Distribution of age in groups by bone mineral density

Bone mineral density (DEXA)	Number (%)	Age	SD	Minimal age	Maximal age
Normal	43 (32.82)	63.33	9.8	49	81
Osteopenia	55 (41.98)	64.6	8.99	49	84
Osteoporosis	33 (25.19)	67.73	8.27	51	81
Total	**131**	**64.97**	**9.18**	**49**	**84**

The higher cortical thickness (mm) or Mental Index (MI) was observed among females with normal bone mineral density, and lower – among females with osteoporosis. Statistically significant difference was observed in all groups for right side measurements (p=0.0007) and left side measurements (p=0.0004) (Table 2).

To obtain more accurate results difference between pairs with different bone mineral density was analysed. There was no statistically significant difference between normal group and osteopenia group (right side p=1.00; left side p=0.617). Whereas there were statistically significant differences in Mental Index among females with normal bone mineral density and osteoporosis (right side p=0.005; left side p=0.009), and between females with osteopenia and osteoporosis (right side p=0.001; left side p<0.001).

There was no statistically significant difference between Mental Index on right and left side (p=0.913).

Table 2

Distribution of Mental Index (MI) in groups by bone mineral density

DEXA	N	MI dex (mm)	SD	MI dex (mm)	SD
Normal	43	3.35	0.75	3.42	0.81
Osteopenia	55	3.21	0.94	3.18	0.9
Osteoporosis	33	2.57	1.01	2.56	1.09
p value of the difference		**0.0007**		**0.0004**	

Mental Index (MI) measurement error for each observer is small (Table 3).

Measurement error for first and second observer and for second and third observer is small. Measurement error for right side measurements is small for first and third observer, yet it is slightly over acceptable limit for left side measurements for first and third observer (Table 4).

Table 3

Measurement error of each observer (Dahlberg's coefficient <1)

Observers	dex	sin
1. observer	0.82	0.61
2. observer	0.05	0.06
3. observer	0.36	0.48

Table 4

Interobserver error and measurement error (Dahlberg's coefficient <1)

	1.observer		2.observer	
2. observer	0.79 (dex)	0.89 (sin)		
3.observer	0.8 (dex)	**1.0 (sin)**	0.36 (dex)	0.48 (sin)

Using Mental Index as a method to separate females with reduced bone mineral density, optimal sensitivity and specificity was obtained to separate females with osteoporosis at the MI threshold $\leq$ 3 mm (Table 5 and Table 6). Sensitivity and specificity among observers and measurements did not differ significantly (Table 7 and Table 8).

Table 5

Sensitivity and specificity of Mental Index to distinguish between females with various DEXA and MI thresholds

1. **observer**		**DEXA L2-L4 and *total hip mean* T-score**		
		≤ -1 SD	**≤ -2 SD**	**≤ -2.5 SD**
Diagnostic threshold of MI **≤ 2.5 mm**	Sensitivity %	31,81 %	42,86 %	48,48 %
	Specificity %	90,70 %	86,59 %	83,67 %
Diagnostic threshold of MI **≤ 3 mm**	Sensitivity %	55,68 %	63,27 %	**72,73 %**
	Specificity %	58,14 %	56,10 %	**56,12 %**
Diagnostic threshold of MI **≤ 4 mm**	Sensitivity %	87,50 %	89,80 %	93,94 %
	Specificity %	20,93 %	18,29 %	18,37 %

Table 6

Sensitivity and specificity of Mental Index by DEXA threshold and bone mineral density determination area

1. **Observer (MI≤ 3 mm)**		DEXA L2-L4, *total hip mean*	DEXA L2-L4	DEXA *total hip mean*
DEXA threshold (≤-1 SD)	Sensitivity %	55,68 %	55,84 %	62,96 %
	Specificity %	58,14 %	60,00 %	60,27 %
DEXA threshold (≤-2 SD)	Sensitivity %	63,27 %	67,39 %	58,33 %
	Specificity %	56,10 %	58,33 %	52,43 %
DEXA threshold (≤-2.5 SD)	Sensitivity %	72,73 %	**76,67 %**	63,64 %
	Specificity %	56,12 %	**57,00 %**	51,72 %

Table 7

Sensitivity and specificity of Mental Index (MI ≤ 3 mm) to distinguish between females with reduced bone mineral density (T- score ≤-1 SD) (worst total hip mean and L2-L4 reading)

Observer and measurement		**Sensitivity %**	**Specificity %**
1.observer	1.measurement	55,68 %	58,14 %
	2.measurement	65,91 %	55,81 %
2.observer	1.measurement	64,77 %	51,16 %
	2.measurement	64,77 %	46,51 %
3.observer	1.measurement	64,77 %	53,49 %
	2.measurement	70,54 %	51,16 %
Mean (min-max)		**64,4 (55,68-70,54)%**	**52,71(46,51-58,14)%**

Table 8

Sensitivity and specificity of Mental Index (MI ≤ 3 mm) for different observers to distinguish between females with osteoporosis (T- score ≤-2.5 SD) (worst total hip mean and L2-L4 reading)

Observer and measurement		**Sensitivity %**	**Specificity %**
1.observer	1.measurement	72,73 %	56,12 %
	2.measurement	81,82 %	48,98 %
2.observer	1.measurement	78,79 %	46,94 %
	2.measurement	75,76 %	43,88 %
3.observer	1.measurement	78,79 %	47,96 %
	2.measurement	81,81 %	42,86 %
Mean (min-max)		**78,28 (72,73-81,82)%**	**47,79 (42,86-56,12)%**

In 86.96% of cases females with mandibular Cortical Index C1 had a normal bone mineral density. Normal bone mineral density as well as osteopenia and osteoporosis were observed among females with mandibular Cortical Index C2. Among females with mandibular Cortical Index C3 osteoporosis was observed in 64.52% of cases. There was statistically significant difference between groups ($p<0.001$) (Table 9).

Table 9

Distribution of Cortical Index (C) in groups by bone mineral density (p<0.001)

	C1	C2	C3
Normal	**20 (86,96%)**	18 (23,38%)	5 (16,13%)
Osteopenia	2 (8,7%)	**47 (61,04%)**	6 (19,35%)
Osteoporosis	1 (4,35%)	12 (15,58%)	**20 (64,52%)**

Intraobserver agreement for mandibular Cortical Index was prominent for first observer (k-0.89), and very good for second (k-0.76) and third observer (k=0.69).

Combined interobserver agreement for first and second measurements was very good (k-0.63 and k-0,61).

For Cortical Index (any unevenness – C2 and C3) as a method to distinguish between females with reduced bone mineral density(worst total hip mean and L2-L4 reading) and females with normal bone mineral density sensitivity was 94.13% and specificity – 38.76%). However, using marked unevenness (C3) as a method, optimal sensitivity and specificity of method was observed when distinguish between females with osteoporosis and others (Table 10, 11 and 12).

Table 10

Sensitivity and specificity of Cortical Index (C) to distinguish between females with different bone mineral density (worst total hip mean and L2-L4 reading)

1.observer		**DEXA (L2-L4, *total hip mean)* T-score**		
		≤ -1 SD	**≤ -2 SD**	**≤ -2.5 SD**
Diagnostic threshold **C2 and C3**	Sensitivity %	**96,59 %**	97,96 %	96,97 %
	Specificity %	**46,51 %**	36,67 %	22,45 %
Diagnostic threshold **C3**	Sensitivity %	29,55 %	48,98 %	**60,60 %**
	Specificity %	88,37 %	91,46 %	**88,78 %**

Table 11

Sensitivity and specificity of Cortical Index (C2 and C3) to distinguish between females with reduced bone mineral density (T- score ≤-1 SD) (worst total hip mean and L2-L4 reading)

Observer and measurement		**Sensitivity %**	**Specificity %**
1.observer	1.measurement	96,59 %	46,51 %
	2.measurement	95,45 %	39,53 %
2.observer	1.measurement	90,91 %	46,51 %
	2.measurement	92,05 %	39,53 %
3.observer	1.measurement	94,32 %	27,91 %
	2.measurement	95,45 %	32,56 %
Mean (min-max)		**94,13 (90,91-96,59) %**	**38,76 (32,56-46,51) %**

Table 12

Sensitivity and specificity of Cortical Index (C3) to distinguish between females with osteoporosis (T- score ≤-2.5 SD) (worst total hip mean and L2-L4 reading)

Observer and measurement		**Sensitivity %**	**Specificity %**
1.observer	1.measurement	60,60 %	88,78 %
	2.measurement	57,58 %	89,80 %
2.observer	1.measurement	51,51 %	87,76 %
	2.measurement	45,45 %	87,76 %
3.observer	1.measurement	30,30 %	90,82 %
	2.measurement	36,36 %	91,10 %
Mean (min-max)		**46,97 (30,3-60,6) %**	**89,34 (88,79-91,1) %**

There was no significant correlation between Mental Index, weight and BMI. However, correlation between Mental Index and height was weak. Mental Index increased with increased height (Table 13).

Table 13

Correlation coefficients and determination for Mental Index, height, weight and BMI

	MI dex	**MI sin**
Height	**0.260 (6.76%)** **p=0.03**	**0,259 (6,71%)** **p=0.03**
Weight	0.086 (0.74%) p=0.331	0.145 (2.1%) p=0.099
BMI	-0.029 (0.08%) p=0.747	0.035 (0.12%) p=0.696

In order to assess relationship between weight, height, BMI and Cortical Index patients were divided into 3 groups by Cortical Index. There were 23 females with Cortical Index C1 (mean age 60.17 ±10.38 years), 77 females with C2 (mean age 64.70±8,86 years) and 31 female with C2 (mean age 69.19 ±7.15 years) (Table 14). The age differences between groups were statistically significant (p=0.01).

Table 14

Distribution of age in groups by Cortical Index

Cortical Index	**Number**	**Age**	**SD**	**Minimal age**	**Maximal age**
C1	23	60,17	10,38	49	81
C2	77	64,70	8,86	49	84
C3	31	69,19	7,15	56	80
Total	**131**	**64,97**	**9,18**	**49**	**84**

The highest values of height, weight and BMI were observed for females with Cortical Index C1, and lowest values – for females with Cortical Index C3. There were statistically significant differences between all three Cortical Index groups by weight (p=0.009), height (p=0.001) and BMI (p=0.024).

Analysis of difference in each group did not show statistically significant difference by height between C2 and C3 groups (Table 15).

No statistically significant differences by weight were observed between C2 and C3 groups and between C1 and C3 groups (Table 16).

No statistically significant difference by BMI was observed between C1 and C2 groups (Table 17).

Table 15

Distribution of height in groups by Cortical Index

Cortical Index	C1	C2	C3
N	23	77	31
Height (cm)	**164.91**	**159.04**	**160.35**
SD	5.72	6.27	5.75

p=0.001 p=0.928 p=0.021

Table 16

Distribution of weight in groups by Cortical Index

Cortical Index	C1	C2	C3
N	23	77	31
Weight (kg)	**78.3**	**72.49**	**66.48**
SD	14.46	14.1	12.17

p=0.236 p=0.128 p=0.007

Table 17

Distribution of body mass index in groups by Cortical Index

Cortical Index	C1	C2	C3
N	23	77	31
BMI	**28.82**	**28.65**	**25.76**
SD	5.46	5.42	4.13

p=0.098 p=0.028 p=0.028

4.1.1. Use of removable dentures and x-ray indices of jawbone

For patients with removable dentures lower vales of Mental Index were observed. However, these differences were not statistically significant (right side p=0.2314; left side p=0.09621; mean p=0.1439) (Table 18).

There was also no statistically significant difference of Cortical Index between groups (p=0.44) (Table 19).

Table 18

Mean values of Cortical Index by use of dentures

	With dentures		**Without dentures**		**p value of the difference**
	Mean	**SD**	**Mean**	**SD**	
Number	42		42		
MI dex	2,95	0,94	3,21	1,02	0,2314
MI sin	2,88	0,96	3,26	1,08	0,0961
MI mean	2,92	0,93	3,23	1,04	0,1439

Table 19

Distribution of Cortical Index in groups by use of dentures (p=0.44)

	With dentures	**Without dentures**
C1	4 (9,52%)	8 (19,05%)
C2	28 (66,67%)	24 (57,14%)
C3	10 (23,81%)	10 (23,81%)

4.2. Osteoporosis and loss of teeth in postmenopausal women

Study „A"

According to the DEXA results all females were dividend into 3 groups: females with normal bone mineral density – 25 (mean age 61.56 ± 9.8 years), females with osteopenia -36 (mean age 62.17± 8.54 years), and females with osteoporosis - 18 (mean age 66.22 ± 9.47 years). The age differences between groups were not statistically significant (p=0.215).

The number of preserved teeth in different groups (normal bone mineral density, osteopenia and osteoporosis) were almost similar. There were no statistically significant differences between groups in respect to the total number of teeth left

(p=0.9926), and number of teeth in maxilla (p=0.9064) and mandibula (p=0.6821) (Table 20).

No correlation between number of teeth and DEXA readings was found (Table 21). Weak correlation was observed between number of maxillary posterior teeth and DEXA measurements in hips (Table 22).

Table 20

Distribution of number of teeth in groups by bone mineral density

DEXA	Number of patients	Number of teeth in maxilla	Number of teeth in mandibula	Number of all teeth
Normal	25	7,52	9,2	16,72
Osteopenia	36	7,19	9,69	16,89
Osteoporosis	18	7,83	8,78	16,61
p value of the difference		**0,9064**	**0,6821**	**0,9926**

Table 21

Correlation coefficients and determination for number of teeth and DEXA

DEXA	Number of teeth in maxilla	Number of teeth in mandibula	Number of all teeth
L2-L4	-0,08 0,64% p=0.489	-0,049 0,24% p=0.668	-0,071 0,5% p=0.535
Total hip mean	-0,162 2,62% p=0.156	-0,082 0,67% p=0.478	-0,136 1,85% p=0.234
Worst DEXA L2-L4 and *total hip mean*	-0,066 0,44% p=0.562	-0,023 0,05% p=0.843	-0,51 0,26% p=0.656

Table 22

Correlation coefficients and determination for number of frontal and posterior teeth and DEXA

DEXA	**Maxillary frontal teeth**	**Maxillary posterior teeth**	**Mandibular frontal teeth**	**Mandibular–posterior teeth**
L2-L4	-0,107 (1,15%) p=0.353	-0,043 (0,18%) p=0.706	-0,067 (0,45%) p=0.561	-0,024 (0,06%) p=0.832
Total hip mean	-0,058 (0,37%) p=0.617	**-0,228** **(5,2%)** **p=0.045**	0,079 (0,62%) p=0.494	-0,145 (2,1%) p=0.205
Worst DEXA L2-L4 and *total hip mean*	-0,064 (0,41%) p=0.575	-0,058 (0,34%) p=0.612	0,026 (0,07%) p=0.819	-0,042 (0,18%) p=0.711

Study „B”

Worst DEXA readings were observed among edentulous females in comparison to females with preserved teeth. However, this difference was not statistically significant between groups (Table 23).

Among edentulous females 30,61% had a normal bone mineral density and 30.61% - osteoporosis.

Among females with preserved teeth 24,49% had normal bone mineral density and 26.53% - osteoporosis.

No statistically significant difference between groups was found (p=0.589) (Table 24).

Table 23

Distribution of DEXA readings in groups by number of teeth

	Edentulous		With teeth		p value of the difference
	Value	**SD**	**Value**	**SD**	
Number	49		49		
DEXA L2-L4	-1,58	1,48	-1,32	1,60	0,4013
DEXA *total hip mean*	-1,05	1,18	-0,73	1,07	0,1676
Worst DEXA	-1,72	1,3	-1,56	1,28	0,527

Table 24

Distribution of bone mineral density in groups by number of teeth (p=0.589)

DEXA	Edentulous	With teeth
Normal	15 (30,61%)	12 (24,49%)
Osteopenia	19 (38,78%)	24 (48,98%)
Osteoporosis	15 (30,61%)	13 (26,53%)

4.3. Osteoporosis and alveolar bone resorption of edentulous jaws in postmenopausal women

According to the DEXA results all females were dividend into 3 groups: females with normal bone mineral density – 15 (mean age 65.53 ± 9.05 years), females with osteopenia -20 (mean age 68.4± 8.71 years), and females with osteoporosis - 15 (mean age 69.53 ± 6.42 years) (Table 25). The age differences between groups were not statistically significant (p=0.391).

Table 25

Distribution of age in groups by bone mineral density

DEXA	Number	Age	SD	Minimal age	Maximal age
Normal	15	65,53	9,05	51	76
Osteopenia	20	68,4	8,71	56	84
Osteoporosis	15	69,53	6,42	57	78
Total	**50**	**67,88**	**8,2**	**51**	**84**

In respect to the measurements of maxillary alveolar bone, lowest X4sin height (mm) was observed in osteoporosis group, and this difference between group was statistically significant (p=0.0399). No statistically significant differences between various bone mineral density groups were observed in respect to other measurements (Table 26).

No statistically significant difference between groups was observed in respect to the mandibular measurements of h (right side p=0.9658; left side p=0.1378) and Y1 (p=0.6852). Among females with osteoporosis a trend toward lower values of H (mm) was observed (right side p=0.0987; left side p=0.0609) (Table 27).

Table 26

Distribution of maxilla height in groups by bone mineral density

Factor	**Measurements (mm) of maxilla alveolar bone height**			**p value of the difference**
	Normal (SD)	**Osteopenia** (SD)	**Osteoporosis** (SD)	
X1	**11.64** ± (3.56)	**13.38** ± (2.58)	**13.34** ± (3.85)	0.2486
X2 dex	**9.85** ± (2.85)	**11.67** ± (2,95)	**11.74** ± (2.51)	0.1127
X2 sin	**11.8** ± (3.18)	**11.39** ± (2,67)	**12.01** ± (2.75)	0.813
X3 dex	**2.53** ± (1.49)	**3.39** ± (3)	**2.88** ± (2,06)	0.5604
X3 sin	**2.39** ± (1.73)	**2.85** ± (2,02)	**2.67** ± (1,69)	0.7698
X4 dex	**8.47** ± (2,84)	**8.59** ± (3,4)	**7.73** ± (3)	0.7276
X4 sin	**8.04** ± (3.2)	**9.4** ± (2.49)	**6.76** ± (2.82)	**0.0399**

Table 27

Distribution of mandibular height in groups by bone mineral density

Factor	Measurements (mm) of mandibular alveolar bone height			p value of the difference
	Normal (SD)	**Osteopenia** (SD)	**Osteoporosis** (SD)	
Y1	**17.89** (4.09)	**19.11** (4.4)	**18.1** (4.73)	0.6852
H dex	**15.57** (3.82)	**18.53** (5.65)	**14.98** (4.46)	**0.0987**
h dex	**9.46** (1.98)	**9.53** (2.56)	**9.29** (2.65)	0.9658
H sin	**16.76** (4.61)	**18.42** (5.81)	**14.29** (3.46)	**0.0609**
h sin	**10.14** (1.53)	**9.54** (2.14)	**8.57** (2.37)	0.1378

ANOVA analysis did not show statistically significant relationship between MR and bone mineral density (MR dex; *r*=-0.03; p=0.993; 95%CI -0.629; 0.623; MR sin coefficient=0.121; p=0.728; 95%CI-0.577; 0.819).

No correlation was found between BMI and measurements of mandibular and maxilla alveolar bone height (Table 28 and Table 29). No correlation was found also between BMI and MR (MR dex correlation coefficient and correlation - 0.04; 0.16% p=0.797; MR sin – correlation coefficient and correlation -0.013, 0.017%, p= 0.934 (Sperman's rho correlation).

In general, there were no correlation between measurements of alveolar bone height and body height. The only exception was Y1, where correlation coefficient was 0.282 (Pearson correlation p=0.05) (Table 28 and Table 29).

There is no relationship between BMI and measurements of alveolar bone height (Table 28 and Table 29).

Measurement error for different measurements was small (Dahlberg's coefficient 0.31-0.92).

Table 28

Correlation coefficients and determination between maxilla alveolar bone height and body mass index (BMI), height and weight (Pearson correlation)

	X1	X2 dex	X2 sin	X3 dex	X3 sin	X4 dex	X4 sin
BMI	-0.302 9.12% p=0.063	-0.246 6.05% p=0.085	-0.021 0.04% p=0.886	-0.110 1.21% p=0.448	-0.038 0.14% p=0.795	0.148 2.19% p=0.327	0.102 1,04% p=0.495
Height	0.227 5.15% p=0.114	-0.058 0.34% p=0.689	0.055 0.30% p=0.706	-0.109 1.19 % p=0.453	-0.264 6.97% p=0.067	-0.135 1.82% p=0.373	0.017 0.03% p=0.911
Weight	-0.210 4.41% p=0.142	-0.267 7.13% p=0.061	-0.020 0.04% p=0.891	-0.135 1.82% p=0.352	-0.123 1.51% p=0.400	0.106 1.12% p=0.484	0.105 1.10% p=0.483

Table 29

Correlation coefficients and determination between mandibular alveolar bone height and body mass index (BMI), height and weight (Pearson correlation)

	Y1	H dex	h dex	H sin	H sin
BMI	-0.185 3.42% p=0.204	-0.269 7.23% p=0.078	-0.308 9.49 % p=0.072	-0.119 1.42% p=0.435	-0.069 0.48% p=0.654
Height	**0.282** **7.95%** **p=0.050**	0.234 5.48% p=0.126	0.177 3.13% p=0.250	0.142 2.02% p=0.351	0.042 0.18% p=0.783
Weight	-0.075 0.56 % p=0.609	-0.172 2.96% p=0.263	-0.220 4.84% p=0.150	0.077 0.59% p=0.619	-0.066 0.44% p=0.668

5 CONCLUSIONS

Mandibular bone structure and thickness OrtPG

1) There was no correlation between cortical bone thickness and weight, and BMI among postmenopausal women, yet there was a trend toward increased thickness of cortical bone among taller women (MI dex $r = 0.260$; $p = 0.03$; MI sin $r = 0.259$; $p = 0.03$).
2) Women with unchanged cortical bone structure were taller, weighted more and had higher BMI (height p=0.001; weight p=0.009; BMI p=0.024).
3) Postmenopausal women with reduced bone mineral density had altered x-ray structure of cortical bone ($p<0.001$), and thinner cortical bone in mental foramen area ($p<0.001$).
4) Use of removable dentures did not affect structure and thickness of cortical bone in postmenopausal women.

Determination of the risk of osteoporosis in postmenopausal women by means of OrtPG

1) Mental Index less or equal to 3 mm indicates high probability of osteoporosis in postmenopausal women (sensitivity 78.28% and specificity 47.79%).
2) Cortical Index C2 and C3 indicates reduced bone mineral density in postmenopausal women (sensitivity 94.13%, specificity 38.76%).
3) Cortical Index is suitable for distinguishing postmenopausal women with reduced bone mineral density, and Mental Index – for distinguishing healthy women. Therefore, Cortical Index and Mental Index should be used for accurate diagnosis of osteoporosis by means of OrtPG.
4) Measurements of Cortical Index and Mental Index are accurate and easy to accomplish.

Osteoporosis and loss of teeth in postmenopausal women

1) In general females with reduced bone mineral density had no higher rate of tooth loss. However, there was a trend toward higher number of lost maxilla posterior teeth among females with low hip bone mineral density (($r = 0.228$; $p = 0.045$).

2) Postmenopausal edentulous women had similar bone mineral density values than women with complete set of teeth and women with partial adentia.

Osteoporosis and alveolar bone resorption of edentulous jaws in postmenopausal women

1) Although trend toward lower alveolar height in mental foramen area with lower bone mineral density was observed (Hdex p = 0.0987; Hsin p = 0.0609), in general resorption of alveolar bone in maxilla and mandibula was not higher among females with reduced bone mineral density.

2) There was no relationship between alveolar bone resorption and weight or BMI. There was trend for taller women to have higher values of mandibular alveolar bone height at centre line (r = 0.282; p = 0.05).

6 SUMMARY

Postmenopausal women with reduced bone mineral density had altered x-ray structure of cortical bone (Cortical Index), and altered thickness (Mental Index). These alterations can be easily recognised in orthopantomogram x-ray images. Therefore, determination of Mental Index and Cortical Index may identify presence of osteoporosis with high level of probability. However, taking orthopantomogram x-ray images to identify osteoporosis is not recommended. They should be used when taken for diagnosis of dental diseases.

This study did not confirm that reduced bone mineral density affects alveolar bone resorption and facilitates loss of teeth. Comparison of these findings with the data from studies in general population would be useful.

7 PUBLICATIONS

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