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Systemic Osteoporosis and Reduction of the Edentulous Alveolar Ridge

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Abstract

Systemic osteoporosis can damage skeletal bones to different degrees or remain persistent in intensity. ***The aim*** of this study was to determine the intensity and correlation of the osteoporotic changes in the bone density of the skeleton and body mass index (BMI) with a reduction in edentulous mandibles.

Material and Methods: In this study, 89 edentulous patients with decreased bone density comprised the experimental group, and 43 edentulous patients with normal bone densities formed the control. The age of the patients ranged between 53 and 73 years. Radiographs of the hands and panoramic radiographs were done for all the patients. The values of BMI, metacarpal index , density of lumbar spine (L2-L4), in the phalanx and segments of the mandibles as well as the heights of the edentulous alveolar ridges were measured, assessed and calculated.

Results: The lowest value of the total skeletal density was established in the osteoporotic patients on the basis of the average T-score of -2.5 in men, and - 2.6 in women. Minimum values of the heights of the edentulous ridges (right/left, in mm) were measured in both osteoporotic female (21.84/22.39) and male (24.90/24.96) patients. By comparison of the densities of the metacarpal bones, proximal phalanx, segments of the edentulous mandibles and based on the numerical values of the heights of the edentulous ridges, χ^2=3.81 was found in men and χ^2=4.03 was found in women with normal bone densities; χ^2=5.92 was found in men and χ^2=6.25 was found in women with osteopenia; χ^2=2.63 was found in men and χ^2=3.85 was found in women with osteoporosis, on the *P* level of probability of 0.05.

Conclusion: Systemic osteoporosis causes a decrease of the jawbone density and induces residual edentulous alveolar ridge reduction.

Keywords: *osteoporosis, jaw, bones, densitometry.*

Introduction

Osteoporosis reduces bone mass and increases bone fragility [1,2]. Data in the literature also indicate the problem of a significant influence of systemic osteoporosis on bone atrophy and a reduction in the residual alveolar ridge of the jaw [3-6], inducing a much greater rate of resorption and the maximum form of a reduced ridge than it would seem at first sight, to be the local factors that affect immediately after tooth extractions [7,8]. However, there is still controversy concerning whether osteoporosis significantly affects the absorption of edentulous alveolar ridges [7, 9-11] or whether its impact on the jaw reduction is insignificant [12-14]. Also, the results based on the previous studies showed the significant role played by the metabolic factors and osteoporosis on the initiation of the reduction of the edentulous residual alveolar ridges [9].

Reduced blood flow to the jaw - particularly in the lower jaw and difficulty in circulation associated with systemic osteoporosis can cause loss of bone substance in the edentulous residual alveolar ridges [15,16]. In addition, if there are signs of alveolar bone resorption under a denture that fits comfortably in the intimate underlying tissue, the causes, in the first place, should be sought in systemic osteoporosis as tissue degradation [17,18].

Difficulties in metabolism and systemic osteoporosis are directly responsible for the appearance of a pronounced reduction in the residual alveolar ridges of the maxilla and mandible [19]. In most of these studies the technique of roentgen dental panoramic monitoring was used, which is confirmed in the literature as the correct approach in the diagnosis and therapy for many diseases of the oro-facial region of edentulous patients as well as in patients with remaining teeth [20].

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A low BMI has also been described as one of the risk factors that may indicate the beginning or the presence of atrophy and resorption of the alveolar ridges, with the fact that patients with low bone mineral density (BMD) may not always have reduced edentulous alveolar ridge, and vice versa. It is also acceptable that patients without supple bone structure and anatomically minor dimensions of the bones usually have significantly marked signs of resorption of the jawbone when compared with a subject with normal BMD and increased BMI [21-24].

The null hypothesis H0 in this study is that there were significant differences in the bone density of different bones within each group with normal bone density, osteopenia or with osteoporosis.

The aim of this study was to determine the intensity and correlation of the osteoporotic changes in the bone density of the skeleton and body mass index (BMI) with a reduction in edentulous mandibles.

Material and Methods

Patients: This study examined all the 132 edentulous patients from 53 to 73 years of age. All patients were treated as outpatients in the Clinic. The experimental group with reduced BMD included 89 edentulous patients (50 females and 39 males). The control group consisted of 43 edentulous patients (25 males and 18 females) with normal bone density (Table 1). All the patients had been edentulous for at least three months or more. The longest period of edentulism was six months in one patient.

Table 1.
Distribution of patients' age by different groups of bone mineral density.

	Women		Men	
T score	***Average age***	***SD***	***Average age***	***SD***
Normal bone density n=43	67.41	5.27	65.12	6.11
Osteopenia n=34	69.45	7.93	67.32	8.47
Osteoporosis n=55	70.27	8.11	74.89	9.05

In order to collect data, the parameters of weight (in kg) and height (in cm) were measured, antero-posterior carpal radiographs (APCR) (Siemens Rtg apparatus, tube Dofoks RX 150/30-50, focus 2 mm), and standardized panoramic radiographs (Kodak T-MAT G) were taken of all the patients in accordance with the predetermined distance on a scale on the plastic chin-holder of the panoramic X-ray unit (Orthopantomograph 10, Serial No. 01492, Siemens, Germany) under the determined conditions (68 KV and 5 mA).

DXA

Data on the BMD at the system level were obtained by scanning the lumbar vertebrae with dual X-ray absorptiometry (DXA) (Lunar DPX-L scanner, General Electric, USA). On the basis of the generally accepted definition of WHO, the patients were divided into a group with normal bone density, a group with osteopenia and a group with osteoporosis (Table 2) [25]. Moreover, the parameters, BMI (in kg/m^2), metacarpal index (MI), the density of the cancellous parts of the metacarpal bones, proximal phalanx and edentulous ridges of the mandible as well as the heights (in mm) of edentulous ridges (VBG) in the areas where the teeth were extracted were assessed.

Table 2.
Distribution of patients into groups by degree of reduction and height of edentulous residual ridge (P=0.752)

T-score L1-L4	**Reduction of edentulous ridges of mandibles**			**Height of edentulous ridge of mandible (mm)**	
	Small	***Moderate***	***Intensive***	***Right***	***Left***
Normal	33	10	0	25.24	25.44
Osteopenia	5	13	5	25.16	25.19
Osteoporosis	2	12	41	23.41	23.64

Metacarpal Index

The MI was calculated based on the measurement of the differences between the width of trabecular-spongy part of the bone and the width of the cortical bone in the middle segment of the second metacarpal bone according to the formula,

MI = width of the spongy portion – cortical thickness/ numerical value of the overall diameter of the middle shaft of the second metacarpal [2,4].

Measurement of the bone density of the second metacarpals

Measurements of the density of the second metacarpal bones were provided based on the AP carpal radiographs. On the radiographic appearances of each of second metacarpal on the AP radiographs of hands, transparent foil was positioned according to the dimensions of the metacarpal contour. Each foil had a number of squares of identical dimensions (2x2mm). A light beam from the densitometer (DT 11 05, England) was transmitted through each square. Data on the metacarpal density were provided as a sum of all of the measured densities through the quadrants which were approximated to the average value [4,11,16].

Measurement of the bone density of the proximal phalanx:

Measurements of the density of the second proximal phalanx bones were provided based on the AP carpal radiographs. On the radiographic appearances of each of proximal phalanx on the AP radiographs of hands, transparent foil was positioned according to the dimensions of the bone conours. Each foil had a number of squares of identical dimensions (2x2mm). A light beam from the densitometer (DT 11 05, England) was transmitted through each square. Data on the proximal phalanx density were provided as a sum of all of the measured densities through the quadrants which were approximated to the average value [4,11,16].

Measurement of the bone density of the lower jaw

The region wherein the lower jaw was missing the lower first molar was determined in this study for measurements of both of bone density and edentulous ridge height. Transparent films with mesh (squares of dimension 2mm x 2mm) were then positioned onto each of the panoramic radiograph of each patient. Numerical values of the digital light-optical densities were recorded using a densitometer (DT 11 05, England) by transmission of a light beam through each square of the region of interest [4,11,16,33,34,35].

Measurement of heights of the edentulous ridges

Two parameters were analyzed on the panoramic radiographs: heights of the mandibular edentulous ridges in the region of the areas formerly occupied by the molar roots, bilaterally. Two control parameters were assigned to the panoramic radiographs in the regions of the distal edges of the retromolar pads, bilaterally. Parameters were established using vertical lines drawn through the midpoints of the mental foramina toward the lower edges of the panoramic radiographs. A segment

of each of these lines at a distance from a point on the upper edge of the mandibular corpus to a point on the lower edge of the corpus was carefully marked as V1d on the right side, as well as for V1l. Similarly, lines were drawn from the distal edge of the retromolar pads vertically to the lower edge of the panoramic radiograph, and the segments of these lines were marked V3d and V3l, respectively. At the midpoint, between the lines V1d and V3d and at the midpoint between the lines V1l and V3l, vertical lines were drawn perpendicular to the lower edge of the panoramic radiograph**.** These lines were termed V2d on the right and V2l on the left. The vertical dimension in this study was measured in the regions of the missing first molars. The heights of the lines so termed were measured using the nanometer scale (Manser, Inox, Switzerland) with divisions of 0.1 mm and measurement error of 0.05 mm [4,11,16,33,34,35].

For statistical analysis of the numerical values of the bone density, mean and standard deviations were calculated. Statistical analysis of data on vertical dimension and digital density of regions of interest of the edentulous ridges was provided on the basis of calculation of the mean and standard deviations (SD), and the coefficients of variation (CV). Correlation of the radiographically revealed and measured height loss of the edentulous ridge Y1 and the digital light density in the segment of the mandible determined was calculated by Pearson's coefficient. Comparison of the measured numerical values of the densities of the second metacarpal bones, proximal phalanx, segments of the edentulous ridges and numerical data on the heights of edentulous ridges was done using the χ^2test and comparing 4 independent samples by the McNemar's test.

Result

The lowered BMI values were in the experimental osteoporotic patient group (Table 3).

Table 3.
Mean values of BMI in examined edentulous patients

BMD	Gender	T-score (avarage)	BMI (mean values)
Normal	Men	0.2	24.1
	Women	0.5	22.2
Osteopenia	Men	-1.9	19.9
	Women	-2.1	18.1
Osteoporosis	Men	-2.5	18.3
	Women	-2.6	16.9

The average skeletal density, determined based on the T score on the DXA record, was the lowest in the osteoporotic experimental patient group, both for men (T=-2.5) and women (T=-2.6), as well. The MI values were noted in the control group at 52.6% on average, with a minimum of 48.23% and a maximum of 56.65% on both hands of the men, and 49.7% on average, with a minimum of 46.93% and a maximum of 52.03% on both hands of the women.

In experimental group with osteopenia, the MI values were noted at 41.9 % on average, with a minimum of 40.08 % and a maximum of 43.37 % on the right hand of the men, and 41.03 % on average, with a minimum of 42.03 % and a maximum of 43.96 % on the left hand of men. In the women, the MI values were noted at 30.1% on average, with a minimum of 38.52 % and a maximum of 41.14 % on the right hand, and 41.2% on average, with a minimum of 39.11 % and a maximum of 42.12 % on the left hand.

In experimental group with osteoporosis, the MI values were noted at 36.76 % on average, with a minimum of 31.89 % and a maximum of 41.93 % on the right hand of the men, and 36.48 % on average, with a minimum of 30.67 % and a maximum of 43.02 % on the left hand of men. In the women, the MI values were noted at 30.91% on average, with a minimum of 29.52 % and a maximum of 33.41 % on the right hand, and 31.27% on average, with a minimum of 29.67 % and a maximum of 34.17 % on the left hand (Fig.1).

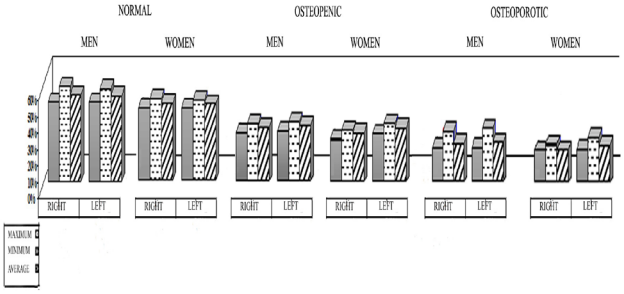

Fig.1.
Values of metacarpal indexes

The lowest measured values of the digital densities of the second metacarpal bones, proximal phalanges as well as the densities of the mandible in the segments where the first molars were missing, and the minimum height of the edentulous ridges were registered in both the men and women with osteoporosis (Table 4).

Table 4.
Average values of digital-light transmitted densities of bones, expressed in U/mm2 in spongy parts of metacarpal bones, proximal phalanx and edentulous ridges of mandibles

BMD (T-score)	Gender	n	Mean density of spongy parts (U/mm²)						Heights of edentulous ridges (in mm)			
			Metacarpal bones		Phalanx proximalis of index		Edentulous ridges of mandibles without molars					
			Right	Left	Right	Left	Right	Left	Right	KV	Left	KV
			X ± SD									
Normal (n=43)	M	25	1.94± 1.23	1.98± 1.14	1.71±1.12	1.78±1.17	2.02±1.12	2.04±1.14	26.22±2.28	8.31	26.24±3.06	8.39
	W	18	1.90±1.11	1.89±1.08	1.69±1.14	1.69±1.13	1.97±1.09	2.01±1.07	24.62±2.09	8.87	24.65±2.12	8.91
Osteopenia (n=34)	M	14	1.19±0.91	1.21±0.88	0.98±0.82	0.99±0.80	-0.85±0.82	-0.82±0.84	25.03±2.82	8.24	25.08±2.84	8.29
	W	20	1.15±0.89	1.11±0.92	0.95±0.78	0.98±0.79	-0.95±0.79	-0.89±0.81	25.29±2.79	8.39	25.31±2.81	8.41
Osteoporosis (n=55)	M	25	0.77±0.71	0.82±0.69	0.56±0.71	0.53±0.69	-1.27±0.69	-1.19±0.63	24.96±0.62	2.43	24.90±2.68	2.19
	W	30	0.68±0.74	0.65±0.72	0.51±0.73	0.52±0.70	-1.81±0.84	-1.80±0.86	21.84±2.28	12.21	22.39±1.91	7.51

**kv- coefficient of variation; X= mean value; SD=Standard deviation*

A positive correlation between the radiologically displayed and measured height of the edentulous ridge Y1 (Table 5) and the digital light density of the bone in the segment of the edentulous mandible between the radiological display and the measured the height of the edentulous ridge Y1 and BMI was calculated (Table 6).

Table 5.
Correlation between radiological measurement of edentulous ridges of mandibles Y1 and digital light transmitted density of segment of edentulous mandible

		Y1
Density	Pearson correlation	0.049 (**)
	P value	0.006
	Number of patients	89

Correlation was estimated for probability of P=0.01

Table 6.
Correlation between radiological measurement of edentulous ridges of mandibles Y1 and BMI

		Y1
Body mass index	Pearson correlation	0.038 (**)
	P value	0.009
	Number of patients	89

Correlation was estimated for probability of P=0.01

Based on the comparison of the numerical values that were observed in the analysis of the density of the metacarpal bones, proximal phalanx, segments of the edentulous ridges and numerical data on the edentulous ridges using the $\chi^2$and McNemar's tests, the results were estimated: χ^2= 3.8182 (υ degrees of freedom = 11) in men with normal bone density, χ^2 = 4.0384 (degrees of freedom υ = 12) in women with normal bone density, χ^2 = 5.9238 (degrees of freedom υ = 9) in men with osteopenia, χ^2 = 6.2571 (degrees of freedom υ = 11) in women with osteopenia, χ^2 = 2.6359 (degrees of freedom υ = 5) in men with osteoporosis, χ^2 = 3.8519 (degrees of freedom υ = 6) in women with osteoporosis, the probability level 0.05 (and 5% respectively). Results based on the χ^2 tests showed that the data tested are consistent with H0; thus, the null hypothesis in this study is accepted.

Discussion

Osteoporosis is a systemic skeletal disease characterized by a reduced bone mass with a change in the bone tissue structure, leading to bone fragility and to an increased risk of fracture [1, 2, 26, 27]. The socio-economic factors and global trends of medical technology in today's world have caused the average age and the number of toothless people suffering from osteoporosis to increase [1,2,24].

According to the literature, the extraction of the last remaining teeth activated osteoclasts during the first 6 to 24 months [9,28,29] with later build-up of slower but progressive atrophy with a reduction in the edentulous ridge. Besides, according to the published data [3,5], the systemic factors, which are activated immediately and directly after the action of the local factors, have a greater influence on the reduction of the edentulous jaws.

A statistically significant correlation was observed between the resorption of the edentulous ridges around the mental foramen or distally and osteoporosis proven by DXA in 128 of the edentulous patients [8]. In a similar study, in 92 edentulous patients older than 75 years, osteoporosis was defined based on the analysis of the PRs of the patients with the greatest reduction in the edentulous residual ridge [30]. However, some authors did not find statistically significant differences in the structure and density of the jawbone of those with normal bone density and postmenopausal edentulous women with osteoporotic hip, despite diagnosed reduction in the jaw ridge [7]. In order to determine the absorption and the height of the edentulous jaw ridge in this study, the panoramic radiographs of the patients were used, based on which real and substantial data could be monitored and the measured heights of the edentulous ridges might be displayed, although the measurements of the heights of the edentulous ridges can be realized based on the profile cephalometric radiographs [7], as well as viewed on the basis of the panoramic radiographs [4,6,8,11,16,30-35], selecting and marking at the different reference points, such as the symphysis jaw line, the line across the region of the mental foramen, the ridges where the first molars were missing, as well as the points distal to the retromolar pads. It is considered that there was no statistically significant difference between the numerical values of the measured height of the edentulous residual AR in the midline jaw of the digital panoramic radiograph and the profile cephalometric radiograph [34,35]. The lateral cephalometric radiograph, however, does not provide insight into both the left and right sides of the jaw, because of the superimposed surfaces, which were making measuring the height of the ridge in the lateral region, especially on the right and on the left side, impossible [14,16].

The region wherein the lower jaw was missing the lower first molar was chosen in this study for measurements of both the bone density and height of the edentulous ridge, as in everyday professional practice, the biggest problem of achieving stability of the dentures in the lower jaw is present precisely when jawbone reduction is expressed in the molar areas. There are indications that the region of the first lower molar, among other predictors of the presence of osteoporosis, which may be related to a reduction in the edentulous ridge [16,33]. The results of this research have just shown that in the bone damaged by osteoporosis, the reduction in the edentulous alveolar ridge is larger and more intense (Table 2, Tables 6-7), which is consistent with the assertions by some authors that in the case of diseases such as SO, the first signs displayed in the jaws were the reductions of the edentulous ridges [4, 7, 8, 11, 30], but in contrast with the results of some recent studies.

In terms of correlating the edentulous ridge atrophy, reduction and the resorption in the jaw with osteoporosis, there are data to support that osteoporosis leads to specific osteoporotic reduction along the buccal-lingual direction, which in the late stages is revealed as a reduced ridge in the form of a "knife edge" [36]. This interpretation, however, cannot be accurately compared with the results of this study, given the fact that suitable form of alveolar ridges could be studied based on a 3-D display of the jaw.

In order to determine the total BMD the lumbar region alone was measured in this study, although the DXA measurements of two regions - the lumbar vertebrae (L2-L4) and femur is considered the "gold standard" for diagnosing osteoporosis because of the greater accuracy and increased functionality with a minimal radiation dose [30].

Despite several efforts to prove the causal relationship between the edentulous alveolar ridge reduction and osteoporosis, several of the existing situations in everyday dental prosthetics clinical practice objectively lead therapists into a dilemma on how to analyze and interpret the findings of a patient with a marked reduction in the jaw ridge but having normal bone density or *vice versa*. This prompted the researchers and the scientific community to try to identify the correlation between development and the intensity in the reduction of the edentulous residual alveolar ridges [16, 21, 22, 24, 38] with the BMI value. In a study conducted on 128 edentulous women no significant association between high BMI and non-reduced edentulous alveolar ridges with significantly high values of vertical dimension was found [21].

Knezović - Zlatarić D. et al., also found a significant difference between the different radiological measurements of the edentulous alveolar ridge height of the lower jaw and BMI, on testing 96 edentulous women [22]. Furthermore, in our study on 89 osteopenic and osteoporotic patients, a significant positive correlation between low BMI with low edentulous ridges height, due to their advanced process of reduction was indentified (Table 7).

The metacarpal index is an objective parameter in determining the existence of osteoporosis and assessing the degree of involvement of osteoporosis into the skeleton [11,33,38]. The thickness of the cortex in the shaft of a metacarpal bone in the hand can be related to the overall diameter of its shaft at the same point [2]. In this present study, it was found that the MI values were significantly decreased in patients with osteoporosis.

Conclusion

Systemic osteoporosis causes a decrease of the jawbone density and induces residual edentulous alveolar ridge reduction.

References

1. Kanis AJ. Osteoporosis. 2nd ed. Oxford : Blackwell Science; 1996; pp. 22-47.

2. Birdwood G. Understanding osteoporosis and its' treatment. 1st ed. New York : The Parthenon Publishing group; 1995; pp. 37-50.

3. Atwood DA. Some clinical factors related to rate of resorbtion of residual ridges. J Prosthet Dent 2001; 86(2):119-25.

4. Poštić SD. Analysis of osteoporotic changes in mandible and its'clinical significance [dissertation]. Belgrade: University School of Dental Medicine; 1998. [Dissertation in Serbian].

5. Devlin H, Feguson MWJ. Alveolar ridge resorption and mandibular atrophy. A review of the role of local and systemic factors. Br Dent J 1991; 170(3):101-4.

6. Poštić SD. Changes in mandible due to osteoporosis. Serbian Dental Journal 2007; 54(1):16-27.

7. Von Wowern N, Kollerup G. Symptomatic osteoporosis: a risk factor for residual ridge reduction of the jaws. J Prosthet Dent 1992; 67(5):656-60.

8. Klemetti E, Vainio P. Effect of bone mineral density in skeleton and mandible on extraction of teeth and clinical alveolar height. J Prosthet Dent 1993; 70(1):21-5.

9. Atwood DA, Coy WA. Clinical, cephalometric and densitometric study of reduction of residual ridges. J Prosthet Dent 1971; 26(3): 280-95.

10. Kribbs PJ, Smith DE, Chesnut CHM, Kilcoyne RF. Relationships between mandibular and skeletal bone in an osteoporotic population. J Prosthet Dent 1989; 62(6):703-7.

11. Poštić SD. Interdependence of decrease in density of mandibular osseous layers and systemic skeletal negative remodelling in view of osteoporosis. Glasnik ADJ 2006; 41: 163-76. [Article in Serbian].

12. Balcikonyte E, Balciuniene I, Alekna V. Bone mineral density and radiographic mandibular body height. Baltic Dent Maxillofac J 2003; 5:137-40.

13. Kribbs PJ. Comparison of mandibular bone in normal and osteoporotic women. J Prosthet Dent 1990; 63(2):218-22.

14. Božić M, Ihan Hren N. Osteoporosis and mandibles. Dentomaxillofac Radiol 2006; 35(3):178-84.

15. Rosenquist JB, Baylink DJ, Berger JS. Alveolar atrophy and decreased skeletal bone mass of the radius. Int J Oral Surg 1978; 7(5):479-81.

16. Poštić S. Osteopenic and osteoporotic changes in a segments of mandibles. 1st ed. Belgrade: Zadužbina Andrejević; 2000. pp. 14-83. [Book in Serbian].

17. Baxter JC. Relationship of osteoporosis to excessive residual ridge resorption. J Prosthet Dent 1981; 46(2):123-25.

18. Rowe DJ. Bone loss in elderly. J Prosthet Dent 1983; 50(5):607-10.

19. Bras J, Van Ooij CP, Van der Akker HP. Mandibular atrophy and metabolic bone loss. Mandibular ridge augmentation by combined sandwich-visor osteotomy and resorption related to metabolic bone state. Int J Oral Surg 1985; 14(1):16-21.

20. Scandrett FR, Tebo HG, Miller JT, Quigley MB. Radiographic examination of the edentulous patient. I. Review of the literature and preliminary report comparing three methods. Oral Surg Oral Med Oral Pathol 1973; 35(2):266-74.

21. Klemetti E, Kroger H, Lassila V. Relationship between body mass index and the remaining alveolar ridge. J Oral Rehabil 1997; 24(11):808-12.

22. Zlatarić DK, Čelebić A, Kobler P. Relationship between body mass index and local quality of mandibular bone structure in elderly individuals. J Gerontol A Biol Sci Med Sci 2002; 57(9):M588-93.

23. Kovavić I, Celebić A, Knezović- Zlatarić D, Stipetić J, Papić M. Influence of body mass index and time of edentulousness on the residual alveolar ridge resorption in complete denture wearers. Coll Antropol 2003; 27 Suppl 2:69-74.

24. Ozola B, Slaidina A, Laurina L, Soboleva U, Lejnieks A. The influence of bone mineral density and body mass index on resorption of edentulous jaws. Stonatologia 2011; 13(1) :19-24.

25. National Institute of Health of USA. Osteoporosis prevention, diagnosis, and therapy. NIH Consens Statement 2000 March 27-29; 17(1): 1-45.

26. NIH Consensus Development Panel on Osteoporosis Prevention, Diagnosis, and Therapy. Osteoporosis prevention, diagnosis, and therapy. JAMA 2001; 285(6):785-95.

27. Knezović-Zlatarić D, Čelebić A, Lazić B. Resorptive changes of maxillary and mandibular bone structures in removable denture wearers. Acta Stomatol Croat 2002; 36: 261-65.

28. Zarb GA, Bolender CL, Eckert SE, Jacob RF, Fenton AH, Mericske-Stern R. Prosthodontic treatment for edentulous patients.12th ed. St Louis: Mosby; 2004, pp.44-45.

29. Soikkonnen K, Ainamo A, Xie Q. Height of the residual

ridge and radiographic appearance of bony structure in the jaws of clinically edentulous elderly people. J Oral Rehabil 1996; 23(7):470-75.

30. White SC, Rudolph DJ. Alterations of the trabecular pattern of the jaws in patients with osteoporosis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999; 88(5):628-35.

31. Poštić SD, Krstić MS, Rakočević Z, Jevremović M, Goldner B, Pilipović NZ, Nastić M. Changes in the lower jaw in osteoporotic women patients, approach and possibilities for therapy. Acta Medica Semendrica 1998; 6:161-65. [Article in Serbian].

32. Poštić SD, Jevremović M, Rakočević Z. Mandibular and metacarpal bone densities in osteoporotic women. J Dent Res 1998; 77 (Special issue B):721.

33. Poštić SD, Krstić M, Rakočević Z. Densitometric assessment of mandibular segment and second metacarpal in osteoporotic women. J Dent Res 1998; 77 (Special issue A): 285.

34. Ural C, Bereket C, Şener I, Aktan AM, Akpinar YZ. Bone height measurement of maxillary and mandibular bones in panoramic radiographs of edentulous patients. J Clin Exp Dent 2011; 3(1):e5-9.

35. Lauriņa L, Soboļeva U. Resorption of edentulous alveolar bone. RSU Zinātniskie raksti; 2008, p. 389-97.

36. Nishimura I, Hosokawa R, Atwood DA. The knife -edge tendency in mandibular residual ridges in women. J Prosthet Dent 1992; 67(6):820-26.

37. Hatipoglu H, Ozcan H, Hatipoglu U, Yuksel E. Age, sex and body mass index in relation to calvarial diploe thickness and craniometric data on MRI. Forensic Sci Int 2008; 182(1-3):46-51.

38. Ward VJ, Stephens AP, Harrison A, Lurie D. The relationship between the metacarpal index and the rate of mandibular ridge resorption. J Oral Rehabil 1977; 4(1): 83-9.