Bone Mineral Density and Mandibular Residual Ridge Resorption

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Purpose: This prospective, cross-sectional study evaluated the relationship between bone mineral density (BMD) and the width and height parameters of the mandibular residual ridge. ***Materials and Methods:*** BMD was determined in the lumbar spine and femoral necks by dual energy x-ray absorptiometry (DXA) in 45 edentulous, postmenopausal women (mean age, 72.08 ± 8.53 years) who had used conventional complete dentures for at least 3 years. Measurements of the mandibular residual ridge were performed using cone beam computed tomography (CBCT). Height and width measurements were performed in the midline and adjacent to the mental foramina. Data were analyzed with descriptive and analytic statistics. The relationship between BMD and mandibular height and width measurements was assessed using analysis of variance as well as linear and multivariate regression analyses. Eight patients were excluded from the study because they did not complete both of the required imaging analyses (DXA and/or CBCT). ***Results:*** There was no statistically significant relationship between BMD and mandibular bone height measurements in the midline and both regions of the mental foramina, and no statistically significant relationship existed between BMD and mandibular bone width measurements in the midline and both of the mental foramina regions. ***Conclusions:*** Postmenopausal women with reduced general BMD do not appear to have a reduction in the size of the mandibular residual ridge. *Int J Prosthodont 2014;27:270–276. doi: 10.11607/ijp.3283*

The quality of life for edentulous patients is improved by optimally supported, stable, and well-retained complete dentures. However, this is not always possible due to individual differences in the structure of the jawbone as mediated by residual ridge resorption (RRR). This is a chronic, progressive, irreversible, and cumulative process characterized by sequential stages that first affect buccal and lingual surfaces and, eventually, the alveolar bone crest (Fig 1). Consequently, three-dimensional examination methods, such as cone beam computed tomography (CBCT), are required to best evaluate bone height and width parameters in treatment planning for implant therapy.

In 1962, Atwood postulated anatomical, functional, prosthetic, and metabolic (also osteoporosis) components as important causative factors for RRR.[1] According to the World Health Organization, osteoporosis is the second most common health problem after heart and vascular diseases. Although it can be diagnosed in both men and women, the lifetime risk from osteoporotic fracture over the age of 50 is approximately 40% in women and 13% in men.[2] This finding is related to a rapid decrease in estrogen levels in women, as first described in 1941 by Albright et al.[3]

The relationship between osteoporosis and RRR appears to be controversial,[4,5] and there are few studies in the literature that have determined the resorption of edentulous arches by three-dimensional examination methods. This is an important consideration because the vertical height of the jawbone often appears to be normal or to have minimal signs of resorption in a clinical examination, while buccolingual dimensions may already be severely decreased. A third examination dimension enables clinicians to determine whether evidence of general BMD is associated with mandibular RRR.

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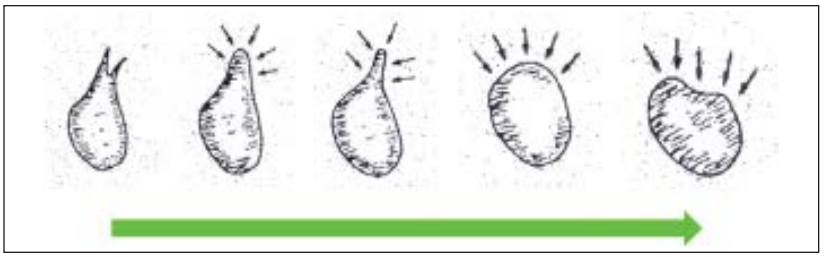


Fig 1 Stages of mandibular RRR. (From Atwood DA. J Prosthet Dent 1963;13:817. Reprinted with permission from Elsevier.)

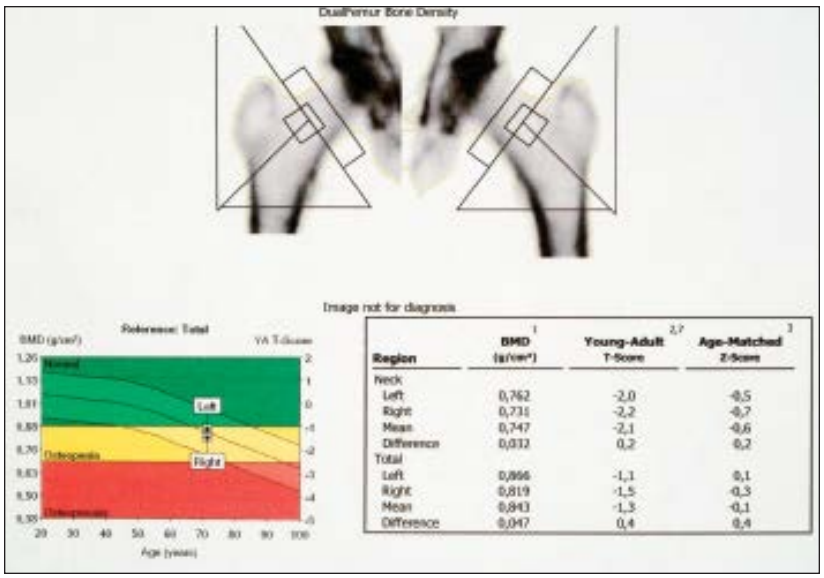


Fig 2 DXA examination in the femoral neck.

The aim of this study was to evaluate the relationship between BMD and the width and height dimensions of the mandibular residual ridge.

Materials and Methods

This prospective cross-sectional study included a convenience sample of 45 edentulous women seeking complete denture treatment. They were aged from 54 to 85 years (mean age, 72.08 ± 8.53 years) and were recruited from the Prosthodontic Clinic at the Institute of Stomatology, Riga Stradins University. All patients agreed to participate in the study, and permission for this research was obtained from the Ethics Commission of Riga Stradins University. The inclusion criteria were as follows: at least 3 years since the beginning of menopause (detected by a patient self-declaration of natural menopause, defined as the permanent cessation of menstrual periods and determined retrospectively after a woman had experienced 12 months of amenorrhea without any other obvious pathologic or physiologic cause); at least 5 years of being edentulous (determined by clinical and radiologic examinations and a dental history questionnaire); and a minimum of 3 years of experience with the use of complete dentures (determined by a dental history questionnaire). The patients in this study were edentulous and menopausal, and they wore complete dentures for a specific period of time, as opposed to a prior study with the same patient group that had inclusion criteria that included menopause, complete dentures, and at least 2 years since the last tooth extraction was carried out.[6] None of the patients had experienced diseases or factors affecting bone metabolism that could cause secondary osteoporosis, and none of the patients were using biphosphonates at the time of the study. It was not possible to collect reliable information as to whether any patient had used biphosphonates prior to their participation in this study. There were no inclusion or exclusion criteria related to any specific T score.

In all patients, BMD was determined in both femoral necks and the L2-L4 lumbar area by DXA using Lunar DEXA DPX-NT (GE Medical Systems) hardware (Figs 2 and 3). According to the World Health Organization`s criteria,[2] the worst possible T score (the number of standard deviations above or below the mean for a healthy 30-year-old adult of the same sex and ethnicity as the patient) from both areas was taken into account.

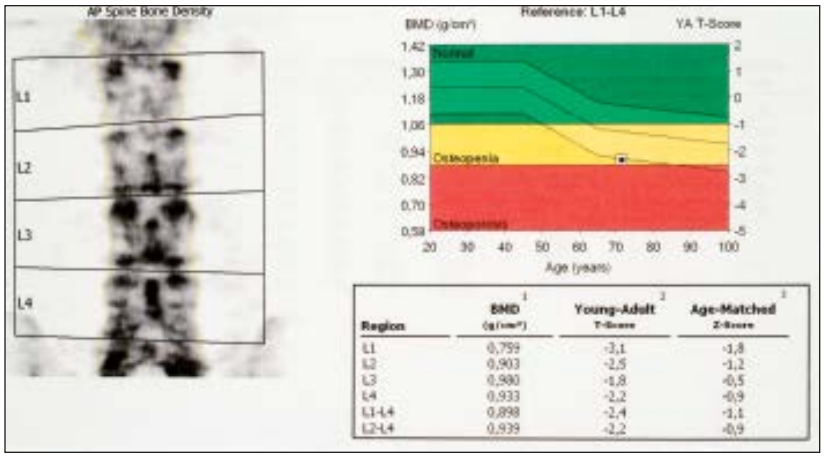


Fig 3 DXA examination in the lumbar spine.

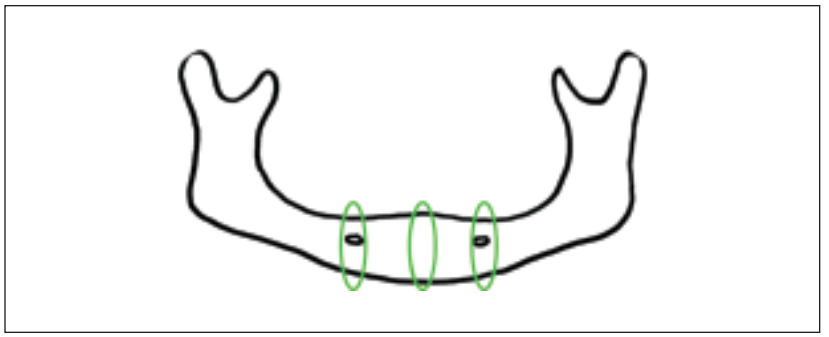
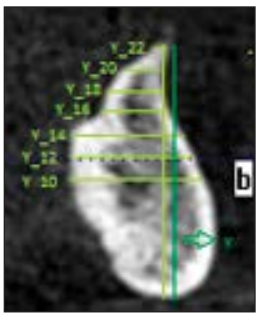
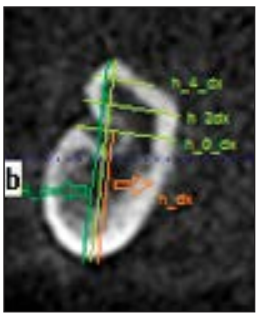


Fig 4 Measurements in the mandibular midline and both regions of the mental foramina.





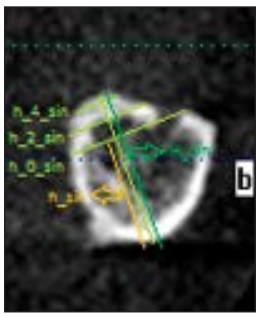


Fig 5 *(left)* Height (Y) and width (Y_10 – Y_22) measurements in the mandibular midline.

Fig 6 *(center)* Height (H_dx, h_dx) and width (h_0_dx – h_8_dx, but in this case h_0_dx – h_4_dx) measurements in the mandibular region of the right mental foramen.

Fig 7 *right)* Height (H_sin, h_sin) and width (h_0_sin – h_8_sin, but in this case h_0_sin – h_4_sin) measurements in the mandibular region of the left mental foramen.

The level of mandibular RRR for each patient was determined by performing 5 height and 17 width measurements in the sagittal plane in the mandibular midline and in both regions of the mental foramina (Fig 4) using CBCT (Next generation i-CAT, Kavo eXam vision). During this examination, all patients were positioned according to the standard protocol.

Height measurements were performed on a line that is parallel to the axial axis of the jawbone, which connects the most upper and lower points of the mandible, respectively, in the midline Y and in the regions of the mental foramina H_dx, H_sin, and h_dx, h_sin, which were measured from the lower border of the mandible to the lower border of the mental foramen (Figs 5 to 7).

Width measurements were performed on a line perpendicular to the height measurement at 2-mm intervals. In the midline, the measurements were obtained 10 to 22 mm above the lower mandibular border, and in the regions of the mental foramina, the measurements were obtained 8 mm above the lower borders of the mental foramina (Figs 5 to 7). Width measurements that projected in the buccal region of the mental foramen, where cortical bone was absent, were measured up to the line that connects the lower and upper borders of the mental foramen. Width measurements that projected above the alveolar crest were regarded as 0 values, which in data analysis were interpreted as missing measurements.

Table 1 Distribution of the Study Group According to the WHO T Score Categories

T score categories	Mean	SD	Minimum	Maximum	Patients (n)
Normal BMD (≥ −1)	−0.240	0.686	−0.90	1.00	10
Osteopenia (−1 to −2.5)	−1.492	0.444	−2.30	−1.00	14
Osteoporosis (≤ −2.5)	−3.138	0.675	−4.20	−1.50	13

The data were analyzed using descriptive and analytical statistical methods. An analysis of variance and linear and multivariate regression analyses were used to define the relationship between BMD and edentulous mandibular residual ridge height and width. The Dahlberg method was used to determine the systemic error of the measurements.

Eight patients were excluded from the study for not completing both of the required imaging studies (DXA and/or CBCT).

Results

All measurements were performed twice, with at least 2 weeks between measurements. Based on the method of Dahlberg, it was estimated that the measurement error was lower than 1.0, indicating that there was no measurement error in the results.

The mean DXA score was −1.732 ± 1.302 (range, −4.2 to 1.0). There were 10 patients with normal bone density, 14 with osteopenia, and 13 with osteoporosis (Table 1).

There was no statistically significant relationship between BMD and the mandibular residual ridge height measurements (Table 2).

A statistically significant relationship was found between general BMD and two width measurements, which were performed in the midline, 16 mm above the mandibular lower border ($P = .033$, $r = 0.496$, 95% confidence interval [CI]: 0.042 to 0.949) and 4 mm above the right mental foramen ($P = .024$, $r = -0.495$, 95% CI: −0.919 to −0.070) (Tables 3 and 4).

Regarding the multivariate regression analysis, there was no statistically significant relationship between general BMD and mandibular residual ridge width measurements performed at one site—in the midline as well as the right and left regions of the mental foramen.

Discussion

Postextraction healing of the alveolar socket and the sequential development of RRR are well described in the literature.[7–9] One hypothesis in the literature is that systemic factors, such as osteoporosis, play a more significant role in RRR than local factors. The premise is that they define the final speed and

Table 2 Relationship Between BMD and the Height Measurements of the Mandibular Residual Ridge in the Midline and Both Regions of the Mental Foramina

	DXA		
Measurement	Coefficient r	*P*	95% CI
H_dx	−0.006	.895	−0.095 to 0.083
h_dx	−0.028	.634	−0.144 to 0.089
Y	−0.055	.424	−0.195 to 0.084
H_sin	0.008	.872	−0.092 to 0.108
h_sin	−0.032	.571	−0.144 to 0.081

BMD = bone mineral density; DXA = dual energy x-ray absorptiometry; CI = confidence interval.

Table 3 Relationship Between BMD and the Width Measurements of the Mandibular Residual Ridge in the Midline

	DXA		
Measurement	Coefficient r	*P*	95% CI
Y_10	0.159	.629	−0.510 to 0.829
Y_12	−0.215	.595	−1.032 to 0.602
Y_14	−0.188	.404	−0.642 to 0.266
Y_16	0.496	.033	0.042 to 0.949
Y_18	−0.175	.327	−0.534 to 0.184
Y_20	−0.196	.286	−0.564 to 0.173
Y_22	0.170	.460	−0.295 to 0.635

BMD = bone mineral density; DXA = dual energy x-ray absorptiometry; CI = confidence interval.

Table 4 Relationship Between BMD and the Width Measurements of the Mandibular Residual Ridge in Both Regions of the Mental Foramina

	DXA		
Measurement	Coefficient r	*P*	95% CI
h_0_dx	−0.052	.737	−0.367 to 0.263
h_2_dx	0.316	.052	−0.002 to 0.634
h_4_dx	−0.495	.024	−0.919 to −0.070
h_6_dx	0.434	.091	−0.074 to 0.942
h_8_dx	−0.226	.277	−0.643 to 0.191
h_0_sin	−0.263	.133	−0.609 to 0.085
h_2_sin	0.259	.070	−0.023 to 0.539
h_4_sin	−0.122	.536	−0.517 to 0.274
h_6_sin	−0.048	.820	−0.478 to 0.381
h_8_sin	0.034	.860	−0.350 to 0.427

BMD = bone mineral density; DXA = dual energy x-ray absorptiometry; CI = confidence interval.

contour of the resorption process when the impact of local factors after the last tooth extraction has already disappeared.[10]

This finding is why the authors chose to study the systemic impact of osteoporosis in patients who had their last tooth loss 5 years prior and who did not have any systemic diseases. In addition to the fact that patients lost their last tooth 5 years prior to this study, it was meaningful to know the reason for, the sequence of, and also the technique of each tooth extraction, because it is possible that the initial resorption of alveolar bone was caused by periodontitis or traumatic tooth extraction. To establish a more homogeneous edentulous study group, all patients received the same design of conventional complete dentures that were made in the same laboratory. In addition, the instructions and recommendations for use were explained to all patients in the same manner.

Previous data suggest that 30% of all Caucasian women after the age of 50 have osteoporosis[2]; therefore, only menopausal patients who were at a higher risk for diminished BMD were included.

Osteoporosis can also occur as a secondary result of other diseases or because of a specific medical therapy. Primary health conditions that frequently cause osteoporosis are juvenile rheumatoid arthritis, diabetes mellitus, osteogenesis imperfecta, hyperthyroidism, hyperparathyroidism, Cushing syndrome, malabsorption syndromes (especially celiac disease), anorexia nervosa, and kidney diseases. In this study, all patients with possible secondary osteoporosis were excluded. In addition, the reliance on questionnaires eliminated risk factors such as excess alcohol consumption, smoking, or eating disorders. Because medical history was collected using a specific questionnaire, there is a possibility that information about diseases or conditions patients may have had but were unaware of having went uncollected and could have influenced the study's results. This study did not consider whether any patient had used biphosphonates prior to this research because it was not possible to collect reliable information. However, after the consumption of antiresorptive drugs, there is the possibility that the DXA results improved but the mandibular ridge parameters were still reduced.

Various studies have investigated the relationship between BMD and jawbone resorption. Although the majority of studies used DXA to determine BMD,[4,11] some researchers preferred a visual analysis of a radiographic image[12] or confirmation of osteoporotic fractures.[13] Additionally, this study used DXA to ensure accurate evaluation of BMD in the L2-L4 lumbar area and in both femoral necks. Currently, this examination method is accepted as the gold standard for the diagnosis of osteoporosis because of its precision, greater functionality, and lower radiation dose.[14] There also are studies that determined BMD in different regions of the mandible by radiography,[15] single- or dual-photon absorptiometry (SPA or DPA),[16] DXA,[17] quantitative computed tomography,[18] or CBCT.[19] However, there are still conflicting opinions as to whether mandibular BMD correlates with skeletal BMD.[18,20] To determine the RRR, authors described different methods, including the clinical classification based on the degree of atrophy,[6] radiographic measurements in the region of the mental foramen,[13,21] radiographic comparison of the jawbone at specific times,[22] measurements of the mandibular symphysis using computed tomography,[23] and other radiographically detected indices at different sites of the mandible.[24]

Also, the aim of the authors' previous study was to determine the relationship between osteoporosis and edentulous jawbone resorption, where BMD was detected in the lumbar spine and femoral necks by DXA, but residual ridge height was measured in the symphysis of the mandible using a digital lateral cephalogram. There was no statistically significant difference between groups when comparing mandibular height changes with different BMD.[6]

After these results, the methodology for the residual ridge measurements was developed by analyzing not only the height but also the width parameters of the mandibular bone. That is why this study used three-dimensional CBCT for the analysis of the jawbone contour. Radiographic measurements were performed in the vertical and sagittal planes to measure edentulous bone height and width. Because data are lacking in the literature, a new method for measurement was developed that determines the amount of mandibular residual ridge through radiographic height and width measurements on CBCT scans. In this study, edentulous arch width measurements were performed using lines that were perpendicular to the height measurement after each 2 mm to detect tiny changes in the mandibular bone width, even with short height intervals. In the midline, this measurement was performed 10 to 22 mm above the lower mandibular border, and in the regions of the mental foramina, it was performed 8 mm above the lower border of the mental foramen. These specific intervals were selected because edentulous jawbone resorption in the buccolingual aspect occurs mostly in the alveolar process, and in this group, these measurements were performed in this anatomical region. Landmarks where width measurements were performed were selected according to provisional measurements. In this study, the highest mandibular height in the midline was 22 mm, but the highest alveolar crest from the lower border of the mental foramen was 8 mm. There were no patients without

any alveolar process remaining where first width measurement would be absent.

In a previous retrospective, cross-sectional study, Nishimura et al[15] analyzed the pattern of RRR, characterizing the longitudinal morphologic changes of the mandibular bony contour in 30 completely edentulous male and female patients. They measured both the sagittal and vertical dimensions of the mandibular bony contour at the symphysis area on longitudinally taken superimposed lateral cephalographic tracings. They developed a knife-edge index as the area change divided by the height change (KEI) to quantify mandibular morphologic changes of labiolingual narrowing with respect to the reduction of the residual ridge height. They also calculated the radiographic bone density of the second vertebra and the center of the mandibular symphysis. They found that the KEI values in women were significantly higher than in men, and a significant correlation was detected between the KEI values and the bone density in the second vertebra. Therefore, they accepted the hypothesis that osteopenic changes in women might be associated with a long-term bone remodeling pattern in the mandible, which results in the knife-edge morphology.[15] This study employed the same hypothesis; however, the results did not confirm this hypothesis. In contrast, they indicated that postmenopausal women with reduced BMD do not have the knife-edge tendency in the residual mandibular ridge. The difference in the present study, which could influence the interpretation and comparison of both study results, is that a methodology was developed for accurate mandibular ridge measurements in the CBCT sagittal plane, not only in the midline but also in both regions of the mental foramina. To detect BMD, DXA was used, which is currently the gold standard. In addition, Nishimura et al performed a retrospective cross-sectional study, whereas the present study is a prospective cross-sectional study.

Until now, an analytic, descriptive survey by Helmi et al[19] was the only published report that investigated the connection between BMD and resorption of the mandibular residual ridge using CBCT scans. The authors found a statistically significant correlation between diminished mandibular BMD and increased levels of RRR. However, this study was limited by a very small patient group, which consisted of six edentulous female patients. In addition, BMD was estimated in the mandible in Hounsfield Units (HU), with the help of a Picasso Trio instrument using CBCT. Unfortunately, CBCT does not allow for the reliable and accurate assessment of bone quality when focusing on the radiographic density information that is expressed by HU. Because BMD not only depends on the calcium content of bone alone but also on the structural characteristics, BMD measurements detected by CBCT do not correlate with BMD measurements detected by DXA.[25] In this study, mandibular height measurements were performed in the coronal CBCT plane in the regions of the mental foramina using Wical and Swoope methodology.[26] Unfortunately, it is impossible to compare these results with the present results because of the different measurement methodologies.[19]

Von Wowern and Kollerup analyzed 28 edentulous women. Of these, 12 women with osteoporotic fractures were considered to have diminished BMD. To grade the RRR of both arches, they used the method of Mercier and La Fontant and compared the jawbones on lateral cephalograms. They found a significantly smaller sagittal maxillary area in the osteoporotic group but no significant difference between the two groups with respect to the size of the mandibular sagittal area.[22] Although they emphasized that osteoporosis is a severe risk factor for maxillary RRR, in the present study, the authors chose to analyze the mandibular bone because of better anatomical landmarks. It is not possible to compare their results with the present results because of the different examination methods that were used to determine BMD and mandibular bone resorption. It is known that osteoporotic fractures could be predictors of osteoporosis, but it is not an exact measurable value, such as DXA. In addition, the degree of precision of the comparison of the arch areas on lateral cephalograms is questionable.

Some studies suggest that osteoporosis affects the quality but not the amount of jawbone. The most described and possibly the most appropriate methods for application in general dental practice to determine the signs of reduced BMD are the Bone Quality Index[27] and the Mandibular Cortical Index.[28] In addition, the measurements of the cortical width of the lower border of the mandible below the mental foramen are widely described as predictors for postmenopausal osteoporosis.[29]

In the present study, a statistically significant relationship between general BMD and the size of the mandibular residual ridge was not found. A statistically significant relationship with a weak correlation was found between general BMD and the two width measurements of the mandibular bone, which could be explained as accidental results that arose from a small study group. Overall, the results of this research are similar to the majority of those published in the literature.[21,24]

Because there is no specific opinion with regard to whether mandibular RRR is predisposed by metabolic, anatomical, functional, prosthetic, or even genetic[30] factors, this study focused on one specific metabolic factor. Despite efforts to establish a homogenous study group, it was not possible to completely exclude other factors that could also affect the speed and the contour of the mandibular RRR, such as functional

(frequency, intensity, duration, and direction of force) and anatomical (specific original anatomical properties, such as mandibular size and shape) components, because, clinically, it is very hard to measure these factors in a meaningful way.

Conclusions

In summary, it can be concluded that postmenopausal women with reduced general BMD do not have a reduced height of the mandibular residual ridge "associated with a reduction in BMD" and do not have buccolingual narrowing or a knife-edge tendency of the mandibular residual ridge.

The authors also conclude that osteoporosis was not the main causative factor for mandibular RRR. Most likely, the main causative factor was the undefined combination of different etiologic factors. That is why in further research the impact of reduced general BMD on RRR should be analyzed in context with other substantial cofactors.

Acknowledgments

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