Rīgas Stradiņa universitāte

Baiba Spriņģe

QUANTITATIVE ASSESSMENT OF MANDIBULAR RESIDUAL RIDGE ON CONE BEAM COMPUTED TOMOGRAPHY IMAGE

Summary of Doctoral Thesis
for obtaining the degree of a Doctor of Medicine

Speciality – Prosthodontics

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The Doctoral Thesis was developed in the Department of Prosthetic Dentistry of Rīga Stradiņš University, Latvia

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The Doctoral Thesis will be available in the library of RSU and on the RSU website: www.rsu.lv

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ABBREVIATIONS

ACP	The American College of Prosthodontists
cm	Centimeter
CT	Computed tomography
Dx	*Dextra* (right)
DXA	Dual energy X-ray absorptiometry
BMD	Bone mineral density
CBCT	Cone beam computed tomography
HU	*Hounsfield* units
L2–L4	2^{nd}–4^{th} lumbar spine vertebrae
mm	Millimeter
OPG	Orthopantomogram
p	Significance level
WHO	World Health Organization
r	*Pearson* correlation coefficient
RRR	Residual ridge resorption
RSU	Rīga Stradiņš University
SD	Standard deviation
Sin	*Sinistra* (left)
CI	Confidence interval
VAS	Visual analogue scale

INTRODUCTION

The major problem in the treatment of the edentulous jaw is the alveolar bone resorption, particularly in the mandible, where the support of conventional complete denture in comparison with the maxilla is anatomically smaller and the amount of alveolar bone for denture users decreases 3 to 4 times faster (*Atwood*, 1971; *Tallgren*, 2003; *Pan* et al., 2010). Reduced mandibular alveolar bone quantity decreases not only the support of conventional complete dentures, but also the stability and retention, which, in turn, contributes to patients` dissatisfaction with dentures. To decrease the rate of the resorption of alveolar residual ridge and improve the result of prosthodontic treatment as well as the quality of life, it is advisable to place 2 to 4 dental implants in anterior area of mandible.

As the reduction of the sagittal alveolar bone width is observed first to the reduction of the alveolar bone height, it is essential to recognize the "knife-edge" shaped mandible. To achieve the desirable sagittal width parameters for tooth implant placement in alveolar bone, osteotomy often is performed. As a result, mandibular alveolar bone height may be reduced significantly, prohibiting further dental implant planning. For edentulous mandibular alveolar bone amount estimation different radiologic examination methods are used, for example, orthopantomogram (OPG). However, the estimation of edentulous mandibular alveolar bone amount, regarding analysis of the both height and width parameters together on three-dimensional images, such as cone beam computed tomography (CBCT), is little described in the literature.

It is postulated in the literature that anatomical, functional, prosthetic, genetic and metabolic components may be important causative factors for residual ridge resorption (RRR) (*Atwood*, 1962; *Kim* et al., 2012). Although there are conflicting opinions in the literature about the relationship between

osteoporosis and alveolar bone amount, there are studies that have shown an association between edentulous mandibular "knife-edge" shaped alveolar bone and reduced general bone mineral density (BMD) (*Nishimura* et al., 1992). However, there are only few studies where edentulous mandibular alveolar bone quantity is determined using CBCT examination method that provides an objective assessment of bone height and also sagittal width parameters.

In the literature reduced residual ridge, especially in the mandible, is associated with patients` dissatisfaction with conventional complete dentures (*Huumonen* et al., 2012). However, these studies have mainly analyzed residual ridge volume, derived solely from the bone height parameters. In order to carry out an objective analysis of the mandibular residual ridge volume impact on patients` satisfaction with conventional complete dentures, appropriate three-dimensional examinations should be performed. The amount of mandibular RRR as well as patients` satisfaction with complete dentures may also be affected by the time. Therefore it would be important to compare the quantitative parameters of mandibular residual ridge and patients` satisfaction with conventional complete dentures in dynamics within a specified time period for which currently no data are available in the literature.

The purpose of the study

To assess the amount of mandibular residual ridge on CBCT image.

The objectives of the study

1. To compare the possibilities of dental implant planning in anterior area of edentulous mandible on CBCT and digital OPG images.
2. To determine the impact of reduced general BMD on mandibular residual ridge quantity.
3. To clarify the relationship between the amount of mandibular residual ridge and patients` satisfaction with conventional complete dentures.
4. To evaluate the changes between mandibular residual ridge amount

and patients` satisfaction with conventional complete dentures during 3 year period.

The hypothesis of the study

1. When planning dental implants in the anterior area of the edentulous mandible there is a significant difference between precise bone measurement options, performed on CBCT or digital OPG images.
2. Reduced general BMD results in significant narrowing of mandibular residual ridge.
3. Reduced amount of mandibular residual ridge is related to patients` dissatisfaction with conventional complete dentures.
4. Using the conventional complete dentures for 3 years, mandibular residual ridge height decreases, as well as the patients` satisfaction.

1. MATERIALS AND METHODS

Initially, to perform 3 different studies, 65 women, aged from 54 to 87 years, were invited to recurrent appointments to the Prosthodontic Clinic at the Institute of Stomatology, Rīga Stradiņš University. In this institution 3 years ago they had received conventional complete dentures for both jaws and had participated in our previous study.

Therefore this patient group had specific inclusion criteria: at least 3 years since the beginning of menopause; at least 5 years of being edentulous; a minimum of 3 years of experience with the use of complete dentures. None of the patients had experienced diseases or factors affecting bone metabolism that may be associated with the resorption of mandibular residual ridge or secondary osteoporosis. None of the patients were using bisphosphonates at the time of the study.

Control appointments attended 53 patients and for each of them digital OPG examination was designated. Later 45 women wanted to find out about the dental implant retained mandibular overdenture treatment, which was why CBCT examination for each of them was indicated.

Since not all 45 patients were able to plan dental implants in the anterior area of edentulous mandible due to insufficient bucco-lingual bone volume, reasons for the RRR were evaluated and the relationship between reduced general BMD and reduction of mandibular residual ridge amount was analyzed. To determine general BMD dual energy X-ray absorptiometry (DXA) for all patients was indicated.

To understand why the most part of the patients expressed a desire to change the existing mandibular conventional complete dentures to dental implant retained overdentures, for all 45 patients subjective satisfaction with the existing mandibular conventional complete dentures using *Likert* visual analogue scale (VAS) was evaluated. Also the relationship between VAS

scores and different mandibular residual ridge measurements, performed on digital OPG as well as on sagittal CBCT images, was analyzed.

Permission for this study was obtained from the Ethics Commission of Rīga Stradiņš University.

1.1. Dental implant planning in the anterior area of edentulous mandible on CBCT and OPG images

This study included 37 women, aged from 54 to 85 years (72.08 ± 8.53).

For each patient digital OPG *(Pantomograph Trophycan C)* and CBCT *(i-CAT, Next generation, Imaging Sciences)* examinations were performed.

In this study it was assumed that it was not possible to place dental implants in the anterior region of edentulous mandible if the sagittal width of mandibular residual ridge was less than 5.0 mm, but height – less than 11.0 mm.

For each patient linear measurements in the mandibular midline and 6 mm mesial from the mesial border of both mental foramina were performed using digital OPG and sagittal CBCT images.

Using digital OPG images (*KODAK Dental Imaging Software 6.3*) parallel line to the mandibular long axis, which connected the most prominent points of the lower mandibular border was drawn. Perpendicular to this line 3 height measurements were performed connecting the lower border of mandible to the alveolar crest. Respectively: OPG_Y_total in the mandibular midline; OPG_6Hdx_total 6 mm mesial from the mesial border of the right mental foramen; OPG_6Hsin_total 6 mm mesial from the mesial border of the left mental foramen (Fig 1.1.1.).

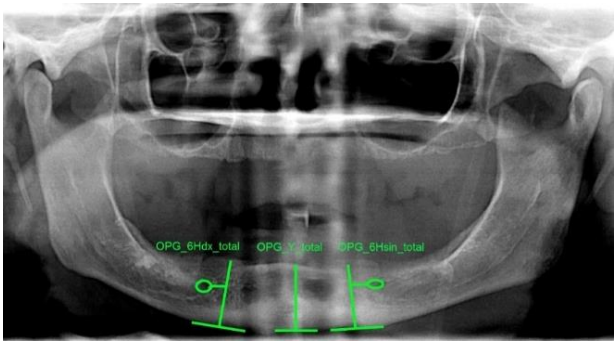
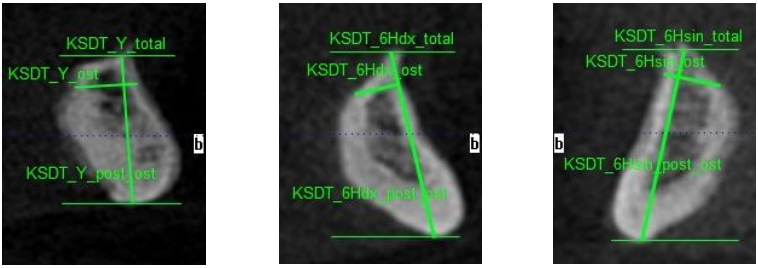


Figure 1.1.1. **Mandibular height measurements on digital OPG image – in the midline and 6 mm mesial from both mesial borders of mental foramina**

On sagittal CBCT images (*ExamVision 1.9, KaVo*) 2 parallel lines were drawn indicating the highest and the lowest points of the mandible. Connecting those 2 points parallel to the mandibular long axis 3 height measurements were performed. Respectively: CBCT_Y_total in the mandibular midline; CBCT_6Hdx_total 6 mm mesial from the mesial border of the right mental foramen; CBCT_6Hsin_total 6 mm mesial from the mesial border of the left mental foramen. Additionally on sagittal CBCT images perpendicular to the height measurements, width measurements were performed, to determine the border of 5 mm sagittal width for dental implant placement (in CBCT scans 5.0–5.5 mm measurements were accepted). Subsequently parallel to the mandibular height measurement the distances above (until the alveolar crest) and below (until the lower border of mandible) were measured, indicating the bone height for osteotomy and the bone height for dental implant placement. Respectively: CBCT_Y_ost and CBCT_Y_post_ost in the mandibular midline; CBCT_6Hdx_ost and CBCT_6Hdx_post_ost 6 mm mesial from the mesial border of the right mental foramen; CBCT_6Hsin_ost and CBCT_6Hsin_post_ost 6 mm mesial from the mesial border of the left mental foramen (Fig 1.1.2. – a, b, c).



a **b** **c**

Figure 1.1.2. **Mandibular height measurements on CBCT sagittal image in the midline (a), 6 mm mesial from the right (b) and from the left (c) mental foramina**

During both radiologic examinations all patients were positioned according to the protocol of Dentomaxillofacial Diagnostic Radiology division, department of Therapeutic Dentistry, Institute of Stomatology, Rīga Stradiņš University. All CBCT images were collected, processed and reconstructed in 0.3 mm voxel matrix.

All measurements were performed twice by 1 measurer (author of the study), with at least 2 weeks between measurements.

The data were analyzed using descriptive and analytical statistical methods. T-test was used to determine if the mean measurements on digital OPG and CBCT images were significantly different. The significance level was accepted as $p < 0.05$. After the method of *Dahlberg* (*Dahlberg* coefficient) measurement error for one measurer between repeated measurements was calculated.

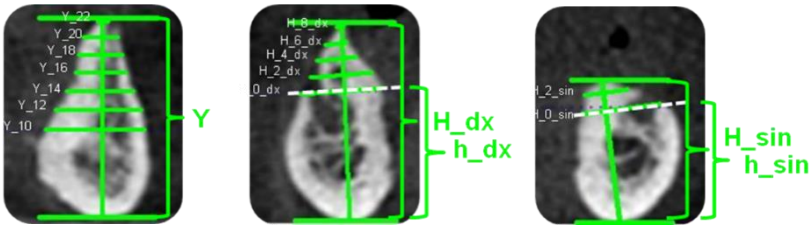
1.2. The influence of reduced general BMD on the quantitative changes of mandibular residual ridge

This study included 38 women, aged from 54 to 83 years (70.08 ± 6.21).

For all patients CBCT *(i-CAT, Next generation, Imaging Sciences)* and DXA (*Lunar DEXA DPX-NT, GE Medical Systems)* examinations were performed.

General BMD was determined in both femoral necks (*total mean*) and the L2–L4 lumbar area using DXA examinations. According to the World Health Organization`s (WHO) criteria, 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 (*WHO Technical Report*, 1994).

The amount of mandibular RRR for all patients was determined by performing 5 height and 26 width measurements on CBCT sagittal images (ExamVision 1.9, KaVo) in the mandibular midline (landmark – the nasal septum) and lateral regions of mental foramina (landmark – anatomically widest part of foramina). Height measurements were performed on a line parallel to the vertical axis of the jawbone, which connected the most upper and lower points of the mandible in the sagittal plane – respectively, in the midline Y and in the regions of the mental foramina H *dx et sin* and h *dx et sin*, which were measured from the lower border of the mental foramen. Width measurements were performed on a line perpendicular to the height measurement at 2 mm intervals. In the mandibular midline measurements were obtained 10–28 mm above the lower border of mandible, respectively, from Y_10 to Y_28, and in the regions of mental foramina – 14 mm above the lower border of mental foramina, respectively, from H_0_dx to H_14_dx on the right, but from H_0_sin to H_14_sin on the left side (Fig. 1.2.1. – a, b, c).



a **b** **c**

Figure 1.2.1. **Mandibular height and width measurements on CBCT sagittal images in the mandibular midline (a), right (b) and left (c) regions of mental foramina**

During CBCT examination all patients were positioned according to the same protocol of Dentomaxillofacial Diagnostic Radiology division, department of Therapeutic Dentistry, Institute of Stomatology, Rīga Stradiņš University. All CBCT images were collected, processed and reconstructed in 0.3 mm voxel matrix.

All measurements were performed twice by 1 measurer (author of the study), with at least 2 weeks between measurements.

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 reduced BMD and amount of mandibular RRR. After the method of *Dahlberg* (*Dahlberg* coefficient) measurement error for one measurer between repeated measurements was calculated.

1.3. The relationship between the amount of mandibular residual ridge and patients` satisfaction with conventional complete dentures

Since patients` satisfaction with mandibular conventional complete dentures was analyzed both cross-sectional and prospectively in 3 year dynamics, 2 study subgroups were created. The cross-sectional study subgroup, in which the relationship between patients` satisfaction with mandibular conventional complete dentures and mandibular residual ridge amount, assessed on both digital OPG and CBCT images, was analyzed, was defined as a “group A” and included 37 patients, aged from 54 to 85 years (72.08 ± 8.53)". In turn, the prospective study subgroup, in which the changes between patients` satisfaction with mandibular conventional complete dentures and mandibular residual ridge amount, evaluated on digital OPG images, during 3-year period, were analyzed, was defined as a "group B" and included 25 patients, aged from 56 to 79 years (69.02 ± 5.42).

For all patients digital OPG *(Pantomograph Trophycan C)* and CBCT *(i-CAT, Next generation, Imaging Sciences)* examinations were performed. Also patients` subjective satisfaction with the existing mandibular conventional complete dentures using *Likert* 100 mm or 10 point VAS (*Awad* and *Feine*, 1998) was evaluated.

Patients` subjective satisfaction with the existing mandibular conventional complete dentures for both groups “A” and “B” using VAS was assessed with 5 questions: 1. Are you satisfied with the mandibular complete denture? 2. Do you feel comfortable while using your mandibular denture? 3. Do you feel pain while using your mandibular denture? 4. Does soreness occur while using your mandibular denture? 5. Is your mandibular denture stable? (*Lauriņa*, 2008) For each patient points from the 1^{st} (VAS_1) and the worst estimated 2^{nd}, 3^{rd}, 4^{th} or 5^{th} (VAS_worst) question were taken into account. To

assess the changes of these indicators in dynamics, patients from "group B" were interviewed 2 times – for the first time at least 2 months after denture delivery, but the second time – 3 years after the use of complete denture.

In addition, no patient had any relining procedures for complete mandibular dentures, since receiving them 3 years ago.

The amount of mandibular RRR for all patients was determined by performing measurements on digital OPG (*KODAK Dental Imaging Software* 6.3) and CBCT (ExamVision 1.9, KaVo) images in the mandibular midline (landmark – the nasal septum) and lateral regions of mental foramina (landmark –foramen midline).

On digital OPG images parallel line to the mandibular long axis, which connected the most prominent points of the lower mandibular border, was drawn. Perpendicular to this line 3 height measurements were performed connecting the lower border of mandible to the alveolar crest. Respectively: OPG_Y_total in the mandibular midline; OPG_Hdx_total on the mandibular right side; OPG_Hsin_total on the mandibular left side (Fig 1.3.1.).

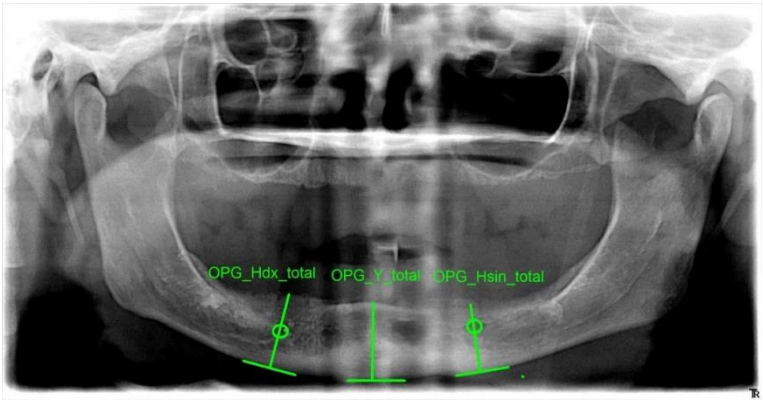
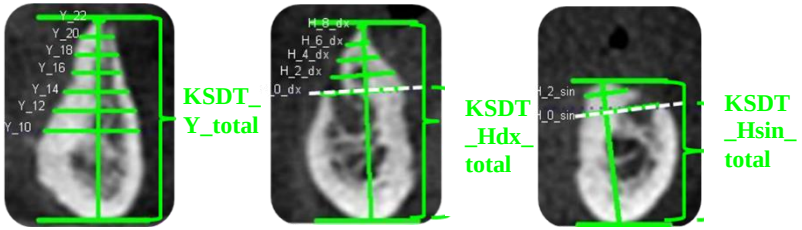


Figure 1.3.1. **Mandibular height measurements on digital OPG image in the midline and lateral regions**

To assess the volume of mandibular RRR in dynamics for "group B" OPG examination and the measurements were repeated twice – for the first time immediately after denture delivery, but the second time – 3 years after the use of complete denture.

On sagittal CBCT images mandibular height measurements were performed on a line parallel to the vertical axis of the jawbone, which connected the most upper and lower points of the mandible – respectively, in the midline CBCT_Y_total and in the regions of the mental foramina CBCT_Hdx_total and CBCT_Hsin_total. Width measurements were performed on a line perpendicular to the height measurement at 2 mm intervals. In the mandibular midline measurements were obtained from 10 mm level above the lower border of mandible up to a height where the width of the measurement reached 0 mm border, and in the regions of mental foramina – from the lower border of foramina to the height where the width of the measurement reached 0 mm border. From all performed width measurements only the most upper measurement in the mandibular residual ridge that for all study group presented values greater than 0 mm, was taken into account. Respectively, in this study population Y_12, H_0_dx and H_0_sin. (Fig. 1.3.2. – a, b, c)



a **b** **c**

Figure 1.3.2. **Mandibular height and width measurements on CBCT sagittal images in the midline (a), right (b) and left (c) regions of mental foramina**

During both radiologic examinations all patients were positioned according to the same protocol of Dentomaxillofacial Diagnostic Radiology division, department of Therapeutic Dentistry, Institute of Stomatology, Rīga Stradiņš University. All CBCT images were collected, processed and reconstructed in 0.3 mm voxel matrix.

All measurements were performed twice by 1 measurer (author of the study), with at least 2 weeks between measurements.

The data were analyzed using descriptive and analytical statistical methods. T-test was used to determine if the mean measurements on digital OPG and CBCT scans were significantly different. The significance level was accepted as $p < 0.05$. For assessment of the correlation between VAS scores and radiological measurements from mandibular residual ridge *Pearson* correlation coefficient (r) was used. After the method of *Dahlberg* (*Dahlberg* coefficient) measurement error for one measurer between repeated measurements was calculated.

2. RESULTS

2.1. Dental implant planning in the anterior area of edentulous mandible on CBCT and OPG images

Based on the method of *Dahlberg (Dahlberg* coefficient*)* it was estimated that the measurement error for measurements performed on CBCT images was 0.00–0.60, indicating that there was no measurement error in the results. However the measurement error on digital OPG images was 1.44–3.21.

There was statistically significant difference (p = 0.000) between mean measurements, performed on CBCT and digital OPG images in mandibular midline (OPG_Y_total and CBCT_Y_total) and mesial from the right (OPG_6Hdx_total and CBCT_6Hdx_total) and left (OPG_6Hsin_total and CBCT_6Hsin_total) mental foramina (Table 2.1.1.).

Table 2.1.1.

Comparison of mandibular residual ridge mean height measurements on OPG and CBCT images in the mandibular midline and 6 mm mesial from both mental foramina

Measurement	Mean value (mm)	SD	p	N
OPG_Y_total	22.83	4.80	0.000	37
CBCT_Y_total	20.57	3.47		
OPG_6Hdx_total	21.67	5.18	0.000	37
CBCT_6Hdx_total	18.92	4.52		
OPG_6Hsin_total	21.28	5.03	0.000	37
CBCT_6Hsin_total	18.79	4.04		

N – number of patients
SD – standard deviation
p – level of significance (p < 0,05)

According to 5.0–5.5 mm width measurement border on CBCT images it was not possible to place dental implants without osteotomy for 100% patients in the mandibular midline as well as 6 mm mesial from both mental foramina.

According to 11 mm height measurement border on digital OPG images it was possible to place dental implants for 100% patients in the mandibular midline as well as 6 mm mesial from both mental foramina. While according to 11 mm height measurement border on CBCT images after osteotomy it was not possible to place dental implants for 10.8% patients 6 mm mesial from the right mental foramen (CBCT_6Hdx_post_ost) and for 10.8% patients 6 mm mesial from the left mental foramen (CBCT_6Hsin_post_ost). Besides for 8.1% patients it was not possible to place dental implants neither 6 mm mesial from the right mental foramen, nor 6 mm mesial from the left mental foramen. (Table 2.1.2.)

Table 2.1.2.

Comparison of mandibular residual ridge mean and minimum height measurements on OPG images before osteotomy and on CBCT images after osteotomy in the mandibular midline and 6 mm mesial from both mental foramina

Measurement	Mean value (mm)	SD	p	Min. value (mm)	How many % can have dental implant	N
OPG_Y_total	22.83	4.80	0.000	13.00	100	37
KSDT_Y_post_ost	18.13	3.04		11.34	100	37
OPG_6Hdx_total	21.67	5.18	0.000	11.20	100	37
KSDT_6Hdx_post_ost	16.34	4.27		5.05	89	37
OPG_6Hsin_total	21.28	5.03	0.000	11.50	100	37
KSDT_6Hsin_post_ost	16.35	3.79		9.24	89	37

Min. – minimum; N – number of patients;
SD – standard deviation; p – level of significance ($p < 0,05$)

2.2. The influence of reduced general BMD on the quantitative changes of mandibular residual ridge

Based on the method of *Dahlberg (Dahlberg* coefficient*)* it was estimated that the measurement error for measurements performed on CBCT images was 0.00–0.46, indicating that there was no measurement error in the results.

The mean DXA T-score was −1.73 ± 1.30 (range from −4.2 to 1.0). There were 11 patients with normal BMD, 14 with osteopenia and 13 with osteoporosis.

There was no statistically significant relationship between general BMD and mandibular residual ridge height measurements in the mandibular midline (Y) as well as in both regions of mental foramina (H_dx, h_dx and H_sin, h_sin) (Table 2.2.1.).

Table 2.2.1.

Relationship between general BMD (DXA) and mandibular residual ridge height and sagittal width measurements (CBCT) in the mandibular midline and both lateral regions of mental foramina

Measurement	BMD			N
	Coefficient	p	95% CI	
Y	−0.03	0.668	−0.16 0.09	38
H_dx	−0.01	0.800	−0.10 0.08	38
h_dx	−0.04	0.634	−0.24 0.15	38
H_sin	0.00	0.971	−0.10 0.11	38
h_sin	0.19	0.118	−0.05 0.43	38

BMD – bone mineral density
N – number of patients
p – level of significance ($p < 0,05$)
CI – confidence interval

There was also no statistically significant relationship between general BMD and mandibular residual ridge width measurements in the mandibular midline (Y_10 to Y_28) (Table 2.2.2.) as well as in both regions of mental foramina (H_0_dx to H_14_dx and H_0_sin to H_14_sin) (Table 2.2.3.).

Table 2.2.2.

Relationship between general BMD (DXA) and mandibular residual ridge sagittal width measurements (CBCT) in the mandibular midline

Measurement	BMD			N
	Coefficient	p	95% CI	
Y_10	−0.01	0.933	−0.26 0.24	38
Y_12	0.05	0.524	−0.12 0.24	38
Y_14	0.03	0.621	−0.09 0.15	38
Y_16	0.05	0.376	−0.07 0.19	38
Y_18	0.58	0.379	−0.07 0.19	38
Y_20	−0.04	0.589	−0.19 0.11	38
Y_22	−0.08	0.431	−0.31 0.13	38
Y_24	−0.20	0.252	−0.54 0.14	38
Y_26	−0.56	0.150	−1.34 0.21	38
Y_28	−1.42	0.198	−3.64 0.78	38

BMD – bone mineral density
N – number of patients
p – level of significance ($p < 0,05$)
CI – confidence interval

Table 2.2.3.

Relationship between general BMD (DXA) and mandibular residual ridge sagittal width measurements (CBCT) in both lateral regions of mental foramina

Measurement	BMD			N
	Coefficient	p	95% CI	
H_0_dx	−0.01	0.894	−0.26 0.23	38
H_2_dx	0.03	0.532	−0.08 0.16	38
H_4_dx	−0.02	0.662	−0.15 0.09	38
H_6_dx	−0.00	0.987	−0.13 0.13	38
H_8_dx	−0.04	0.588	−0.21 0.12	38
H_10_dx	−0.06	0.573	−0.28 0.16	38
H_12dx	0.05	0.766	−0.33 0.45	38
H_14_dx	0.33	0.685	−1.33 2.01	38
H_0_sin	−0.06	0.600	−0.29 0.17	38
H_2_sin	0.00	0.895	−0.13 0.15	38
H_4_sin	−0.02	0.641	−0.14 0.09	38
H_6_sin	−0.05	0.458	−0.18 0.08	38
H_8_sin	−0.09	0.367	−0.29 0.11	38
H_10_sin	−0.11	0.438	−0.40 0.17	38
H_12_sin	−0.22	0.503	−0.89 0.44	38
H_14_sin	–	–	–	38

BMD – bone mineral density
N – number of patients
p – level of significance ($p < 0,05$)
CI – confidence interval

Regarding the multivariate regression analysis, there was no statistically significant relationship between worst general BMD T-score and mandibular residual ridge height and width measurements performed at one site – in the

mandibular midline as well as the right and left regions of the mental foramen.

Regarding patient age, it was estimated that it had no statistically significant relationship with worst general BMD T-score or mandibular residual ridge height and width measurements.

2.3. The relationship between the amount of mandibular residual ridge and patients` satisfaction with conventional complete dentures

Based on the method of *Dahlberg (Dahlberg* coefficient*)* it was estimated that the measurement error for measurements performed on CBCT images was 0.03–0.43, indicating that there was no measurement error in the results. However the measurement error on digital OPG images was 1.44–3.21.

In the "group A" there was no correlation found between patients` satisfaction with mandibular conventional complete dentures (VAS_1 and VAS_worst) and mandibular residual ridge height measurements performed on digital OPG images in the mandibular midline (OPG_Y_total) and both regions of mental foramen (OPG_Hdx_total and OPG_Hsin_total) (Table 2.3.1.).

Table 2.3.1.

"Group A" – *Pearson* correlation coefficient (r) between mandibular residual ridge height measurements (OPG) and patients` satisfaction with mandibular conventional complete denture (VAS)

Measurement	VAS_1	VAS_worst	N
OPG_Y_total	−0.01 (p = 0.917)	0.16 (p = 0.318)	37
OPG_Hdx_total	−0.00 (p = 0.967)	0.18 (p = 0.273)	37
OPG_Hsin_total	0.01 (p = 0.942)	0.16 (p = 0.340)	37

N – number of patients
p – level of significance (p < 0,05)

In the “group A” there was a weak correlation found between patients` satisfaction with mandibular conventional complete dentures (VAS_1) and mandibular residual ridge height measurements performed on sagittal CBCT images in the mandibular midline (CBCT_Y_total) and in the left lateral region of mental foramen (CBCT_Hsin_total). Moderate correlation was found between patients` satisfactions with mandibular conventional complete dentures (VAS_worst) and mandibular residual ridge height measurements performed on sagittal CBCT images in the mandibular midline (CBCT_Y_total) as well as in the right (CBCT_Hdx_total) and left (CBCT_Hsin_total) regions of both mental foramina. (Table 2.3.2.)

Table 2.3.2.

“Group A” – *Pearson* correlation coefficient (r) between mandibular residual ridge height measurements (CBCT) and patients` satisfaction with mandibular conventional complete denture (VAS)

Measurement	VAS_1	VAS_worst	N
KSDT_Y_total	0.38 (p = 0.019)	0.49 (p = 0.002)	37
KSDT_Hdx_total	0.27 (p = 0.096)	0.47 (p = 0.003)	37
KSDT_Hsin_total	0.33 (p = 0.041)	0.56 (p = 0.000)	37

N – number of patients
p – level of significance ($p < 0,05$)

In the “group A” there was no correlation found between patients` satisfaction with mandibular conventional complete dentures (VAS_1) and mandibular residual ridge width measurements performed on sagittal CBCT images in the mandibular midline (Y_12), in the right (H_0_dx) and in the left (H_0_sin) lateral region of mental foramen. Moderate correlation was found between patients` satisfactions with mandibular conventional complete dentures (VAS_worst) and mandibular residual ridge width measurements performed on sagittal CBCT images in the mandibular midline (Y_12), in the right (H_0_dx) and in the left (H_0_sin) lateral region of mental foramen. (Table 2.3.3.)

Table 2.3.3.

"Group A" – *Pearson* correlation coefficient (r) between mandibular residual ridge sagittal width measurements (CBCT) and patients` satisfaction with mandibular conventional complete denture (VAS)

Measurement	VAS_1	VAS_worst	N
Y_12	0.28 (p = 0.089)	0.41 (p = 0.011)	37
H_0_dx	0.32 (p = 0.053)	0.38 (p = 0.019)	37
H_0_sin	0.20 (p = 0.229)	0.34 (p = 0.037)	37

N – number of patients
p – level of significance (p < 0,05)

In the "group B", according to the amount changes of mandibular RRR in 3 years, reduction of mandibular height measurements performed on digital OPG images in the midline (OPG_Y_first and OPG_Y second) was detected, but it was not statistically significant. Statistically significant reduction of mandibular height measurements performed on digital OPG images in the right (OPG_Hdx_first and OPG_Hdx_second) and in the left (OPG_Hsin_first and OPG_Hsin_second) mandibular region of mental foramina was detected. (Table 2.3.4.)

Table 2.3.4.

"Group B" – evaluation of the mandibular RRR amount in 3 years on OPG images in mandibular midline and both regions of mental foramina

Measurement	Mean value (mm)	SD	Difference (mm)	p	N
OPG_Y_first	23.69	4.95	0.46	0.164	25
OPG_Y_second	23.22	5.09			
OPG_Hdx_ first	21.28	5.16	1.16	0.000	25
OPG_Hdx_ second	20.12	5.11			
OPG_Hsin_ first	21.65	4.71	1.66	0.000	25
OPG_Hsin_ swcond	19.98	4.87			

N – number of patients; SD – standard deviation ; p – level of significance (p < 0,05)

In the **"**group B", according to the changes of patients` satisfaction with mandibular conventional complete dentures in 3 years, regarding answer to the 1st question (VAS_1_first and VAS_1_second), patients` dissatisfaction was statistically significantly decreased. According to the changes of patients` satisfaction with mandibular conventional complete dentures in 3 years, regarding answers to the worst estimated 2nd, 3rd, 4th or 5th question (VAS_worst_first and VAS_worst_second), it was found that patients` dissatisfaction was also decreased, but that was not statistically significant.(Table 2.3.5.)

Table 2.3.5.

"Group B" – patients` satisfaction changes in 3 years while using mandibular conventional complete dentures (VAS)

Measurement	Mean value (scores)	SD	Difference (scores)	p	N
VAS_1_first	6.26	3.04	−0.92	0.034	25
VAS_1_second	7.18	2.06			
VAS_worst_first	4.18	2.85	−0.74	0.091	25
VAS_worst_second	4.93	2.00			

N – number of patients
SD – standard deviation
p – level of significance ($p < 0,05$)

3. DISCUSSION

3.1. Dental implant planning in the anterior area of edentulous mandible on CBCT and OPG images

Patients with mandibular conventional complete dentures often complain about discomfort due to RRR and consecutive reduced support, stability and retention of removable dentures (*Batenburg* et al., 1998; *Tallgren*, 2003; Hyland et al., 2009). To decrease the rate of RRR (*Kordatzi*s et al., 2003; *Carlsson*, 2004; *Bodic* et al., 2005), and to improve the result of prosthodontic treatment as well as the quality of life (*Reich* et al., 2011), it is advisable to place 2 to 4 dental implants in anterior area of edentulous mandibular bone (*Feine* et al., 2002).

Studies show that two-dimensional OPG images are not precise enough to identify or measure all anatomical structures of anterior mandibular alveolar bone (*Wismeijer* et al., 1997; *Kaya* et al., 2008; *Ngeow* et al., 2009), while three-dimensional CBCT images provide 100% precise identification of those structures (*Parnia* et al., 2012). Therefore scientific literature affirms that for dental implant planning in anterior area of mandibular alveolar bone three-dimensional X-ray examination methods like CBCT are suggested (*Eufinger* et al., 1997; *Bou Serhal* et al., 2002; *Madriga*l et al., 2008; *Monsou*r and *Dudhia*, 2008; *Angelopoulo*s et al., 2008; *Dreiseidler* et al., 2009; *Georgescu* et al., 2010). Also regarding recommendations of the American Academy of Oral and Maxillofacial Radiology, CBCT should be considered for preoperative cross-sectional imaging of potential implant sites, while OPG should be used as the imaging modality of choice in the initial evaluation of the dental implant patient (*Tyndall* et al., 2012). Following these recommendations in our study, digital OPG as well as CBCT were performed for each patient.

However, when CBCT is performed, the radiation dose should be taken into account. Compared with digital OPG, CBCT represents about 3 to 7 times greater radiation dose, depending on the selected device settings (*Ludlow* et al., 2006; *Dreiseidler* et al., 2009; *Holroyd* and *Gulson*, 2009).

Results of scientific studies suggest that for dental implant supported mandibular overdenture the most distal implant should be placed at least 1 mm mesial from the most mesial point of the anterior loop of the inferior alveolar nerve (*Jensen* et al., 2011). Unfortunately, due to variations of the anatomy of inferior alveolar nerve and its anterior loop there are clear risks in implant placement in this area. Accessory mental foramina (*Naitoh* et al., 2009; *Naitoh* et al., 2010; *Kalender* et al., 2012; *Imada* et al., 2014), which cannot always be localized on OPG in contradistinction to CBCT images (*Santos* u.c., 2013; *Imada* u.c., 2014), are described in the literature. There are also studies that show clinically insignificant length of anterior loop of inferior alveolar nerve (*Rosenquist*, 1996; *Benninger* et al., 2011). The mean (0.9–7.6 mm) and maximum (0.5–9.0 mm) length of anterior loop of inferior alveolar nerve reflected in the literature are of a wide range (*Uchida* et al., 2007; *Uchida* et al., 2009; *Apostolakis* and *Brown*, 2012*; Parnia* et al., 2012; *Rosa* et al., 2013; *Chen* et al., 2013*; Von Arx* et al., 2013). To establish certain methodology, in our study we calculated the arithmetic mean value of the maximum lengths of the anterior loop of inferior alveolar nerve (5.0 mm) from previously represented studies, where the loop was identified. Consequently, on the ground of the recommendation about leaving 1 mm mesial from anterior loop of inferior alveolar nerve (*Jensen* u.c., 2011), the measurement site for distal dental implant placement in mandibular overdenture case in our study was selected 6.0 mm mesial from the mesial border of mental foramen. The third measurement site was selected in the mandibular midline because it is a good anatomical landmark.

Although there is no distinct definition in the scientific literature, what "short" dental implants mean, most authors agree that the length of 10 mm is the boundary between "standard" and "short" dental implants (*Morand* and *Irinakis*, 2007; *Telleman* et al., 2011; *Sun* et al., 2011). As the literature has conflicting opinions about the use of dental implants shorter than 10 mm, showing worse (*Telleman* et al., 2011) or, on the contrary, equivalent (*Triplett* et al., 1991; *Sun* et al., 2011) survival and success rates to "standard" dental implants, in our study we chose the situation where 10 mm long "standard" dental implants were planned for placement in the anterior area of edentulous mandible. According to the classification of the mandibular RRR, established by the American College of Prosthodontists, many patients from this study corresponded to the 3rd and 4th class of RRR, denoting severe bone atrophy and subsequent selection of 10 mm or shorter dental implant selection (*Batenburg* et al., 1998). In our study 11 mm mandibular bone height was accepted as minimum required for the placement of 10 mm long dental implants, including recommended 1 mm distance (*Dietrich* u.c., 1993) to the lower boundary of the mandible.

Dental implants with a diameter less than 3.75 mm are considered as "narrow" dental implants (*Arisan* et al., 2010). Study results show that survival and success rates for a "narrow" diameter dental implants are equivalent to that of the "standard" dental implants, stating they can optimally support overdentures (*Cho* et al., 2007; *Arisan* et al., 2010; *Sohrabi* et al., 2012). Since majority of the patients from our study group had severe mandibular RRR, we planned to select the smallest "standard" dental implants with 3.0 mm diameter that had been recommended for overdenture support. In our study it was assumed that the minimum width of the mandibular residual ridge required for planning of 3 mm diameter dental implant placement was 5 mm, including recommended 1 mm distance (*Dietrich* et al., 1993; *Quirynen* et al., 2003) buccal as well as lingual.

Insufficient bucco-lingual width of mandibular residual ridge often is the reason for osteotomy to flatten "knife-edge" shaped alveolar ridge and to achieve the desired bone width parameters (*Eufinger* et al., 1997). After osteotomy the initial bone height is reduced, which, in fact, may negate the opportunity to place dental implants.

Madrigal et al has published a study of similar methodology (*Madrigal* et al., 2008), which aimed to demonstrate the variations between digital OPG and CBCT examination methods in evaluating the dimensions of alveolar residual ridge and localizing anatomical structures in the anterior area of mandible. This study included 50 patients with complete or partial edentulism in the anterior area of mandible. For each patient digital OPG (*Ortofox Siemens AG*) and CBCT (*NewTom 9000QR*) examinations were performed. Radiologic measurements in the mandibular midline, 1 cm distal from the midline and in the midline of both mental foramina were recorded.

As the aim of our study also was to compare the opportunities of two different X-ray examination methods when planning dental implants in the anterior area of edentulous mandible, similar linear measurements of mandibular alveolar bone using digital OPG and CBCT sagittal images were performed. In our study the mean values of mandibular height measurements, performed on digital OPG images, were statistically significantly higher than the values of sagittal CBCT images. This was on contrary to *Madrigal* study results, of which may be be explained by the optical zoom of digital OPG hardware.

Our results were also in agreement with *Georgescu* study, confirming that mandibular measurements performed with the aid of digital OPG were overestimated, comparing with those obtained by CBCT sagittal scans (*Georgescu* et al., 2010).

According to the width parameters of edentulous mandibular alveolar bone, to place dental implants in our study group in the mandibular midline and

6 mm mesial from both mental foramina, all patients needed to plan osteotomy. While comparing height parameters of edentulous mandibular alveolar bone before osteotomy on two-dimensional OPG images and after osteotomy on sagittal three-dimensional CBCT images, it showed that the difference of those mean measurements was statistically significant. After osteotomy in 10.8% of cases, it was not possible to plan dental implant placement 6 mm mesial from both mental foramina because of insufficient residual alveolar bone height. However, using only OPG examination data, all cases were amenable for planning of dental implant placement in the same area.

It was further shown that in calculating measurement error, there was a significant difference in the accuracy of measurements between OPG and CBCT imaging, in favorite to CBCT. That was also in agreement with the literature, suggesting that the measurement error is greater for the measurements performed on OPG than on CBCT scans (*Hu* et al., 2012).

Our study results clearly underlines the significance of CBCT examination in prosthodontic treatment planning for edentulous jaws to obtain accurate information about opportunities or problems regarding dental implant placement.

3.2. The influence of reduced general BMD on the quantitative changes of mandibular residual ridge

One hypothesis from the literature is that systemic factors, such as osteoporosis, may play a more significant role in RRR than local factors (*Atwood*, 1962; *Kribbs*, 1990). The premise is that osteoporosis may define the final speed and contour of the resorption process when the impact of local factors after the last tooth extraction have already disappeared (*Devlin* and *Ferguson*, 1991; *Bozic* and *Hren*, 2005). Since the most pronounced RRR appears due to local factors at a time 6 to 24 months after the last tooth

extraction (*Atwood*, 1971; *Knezovic-Zlataric* et al., 2002), we therefore in our study included patients who had lost their last tooth at least 5 years prior this study. The shortcomings of this study was the inability to identify the causes and the dynamics of tooth loss, as it is possible that RRR for some patients was induced by periodontitis or traumatic tooth extraction, consequently resulting in greater amount of alveolar bone resorption. However, since several patients before prosthodontics were treated at other dental clinics, such data could not be collected due to the lack of objective information.

To establish a more homogeneous edentulous study group regarding prosthetic factor impact on RRR, all patients 3 years prior this study in the Prosthodontic Clinic at the Institute of Stomatology, Rīga Stradiņš University received similar design conventional complete dentures, which were made in the same dental laboratory. Although the opinions in the literature, whether the use of dentures at night reinforces the amount of RRR (*Campbell*, 1960; *Carlsson*, 2004) or not (*Kovacić* et al., 2010; *Kranjčić* et al., 2013), are controversial, our patients were advised not to use the conventional complete dentures during night.

To observe reduced general BMD, and exclude other metabolic factors that could influence the amount of mandibular RRR, in our study we did not include patients whose medical history showed any systemic diseases or conditions, or use of medications that could cause mandibular RRR. In our study population, based on a survey of patients, the possibility of secondary osteoporosis as well as other osteoporosis-related risk factors, such as alcohol abuse, smoking or diet-related disorders, were also excluded. However, since the medical history was obtained by interviewing patients, there might be a risk that some patients had an undisclosed disease that could affect our study results. We also did not consider whether any patient had used biphosphonates prior this study because it was not possible to collect reliable information. However, it is very important to collect such information prior dental implant

planning because of the risk of jaw osteonecrosis. After the consumption of antiresorptive drugs, there is a possibility that the DXA results could be improved but the mandibular ridge parameters would still be reduced.

Previous data suggest that 30% of all Caucasian women after the age of 50 have osteoporosis (*Albright* et al., 1941; *WHO*, 1994), therefore, we only included menopausal patients who were at a higher risk for diminished general BMD.

Various studies have investigated the relationship between BMD and mandibular RRR. Although the majority of studies used DXA to determine BMD (*Klemetti* et al., 1993a; *Klemetti* et al., 1993b; *Balcikonyte* et al., 2003; *Bozic* and *Hren*, 2005; *Ozola* et al., 2011), some preferred a visual analysis of a radiographic images (*Hirai* et al., 1993; *Soikkonnen* et al., 1996) or the certification of osteoporotic fractures (*Kribbs*, 1990; *Bollen* et al., 2000). There are also studies where BMD was determined in different regions of the mandible by conventional radiography (*Nishimura* et al., 1992), single (SPA) (*Von Wowern*, 1985), or dual (DPA) photon absorptiometry (*Buyukkaplan*, 2012), quantitative computed tomography (QCT) (*Merheb* et al., 2012) or CBCT (*Helmi* et al., 2009). However, there are still conflicting opinions whether mandibular BMD correlates with skeletal BMD (*Cakur* et al., 2009; *Merheb* et al., 2012). In our study, we used DXA to ensure accurate evaluation of general BMD in the L2–L4 lumbar area and in both femoral necks. Currently, this examination method is accepted as the "gold standard" for the diagnostics of osteoporosis because of its precision, greater functionality and lower radiation dose (*National Osteoporosis Society*, 1994).

To determine the RRR, *Klemetti* et al. described different methods, including the clinical classification based on the degree of atrophy (*Klemetti* et al., 1993a; *Soikkonnen* et al., 1996), radiographic measurements in the region of mental foramen (*Kribbs* et al., 1989; *Kribbs*, 1990; *Hirai* et al., 1993; *Bollen* et al., 2000; *Balcikonyte* et al., 2003), radiographic

comparison of the jaw bone at specific times (*Von Wowern* and *Kollerup*, 1992), measurements of the mandibular symphysis using computed tomography (*Klemetti* et al., 1993b) and other radiographically detected indexes at different sites of the mandible (*Bozic* and *Hren*, 2005). In our study we were interested in developing new methodology for the mandibular residual ridge measurements involving not only the height but also the width parameters of the alveolar bone using CBCT images. This method seems objective and repeatable, as there was no systemic errors found associated with the measurements. In this study edentulous jaw width measurements were performed every 2 mm to detect small changes in the mandibular bone width. In the midline, this measurement was performed 10–28 mm above the lower mandibular border, and in the lateral regions, it was performed 14 mm above the lower border of the mental foramina. These specific intervals were selected because edentulous jaw bone resorption in the bucco-lingual aspect occurs mostly in the alveolar process. Landmarks for width measurements were selected according to provisional measurements, respectively, in our study, the highest mandibular height in the midline was 28 mm, but the highest alveolar crest from the lower border of the mental foramen was 14 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., 1992) the pattern of RRR was analyzed, 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 also calculated the radiographic bone density (RD) of the second vertebra and the center of the mandibular symphysis. Finally they suggested that osteopenic changes in women might be associated with a long-term bone remodeling

pattern in the edentulous mandible, which results in the "knife-edge" morphology.

In our study, we were interested in the same hypothesis; however, in contrast, our results indicated that postmenopausal women with reduced BMD do not have the "knife-edge" tendency in the mandibular residual ridge. The difference in our study, which could influence the interpretation and comparison of both study results, was that we developed a methodology 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, we used DXA, which is currently the gold standard. In addition, *Nishimura* et al. performed a retrospective study, whereas our study was a cross-sectional.

Until now, there was only one study (*Helmi* et al., 2009) that investigated the connection between BMD and mandibular RRR using CBCT images. The authors found a statistically significant correlation between diminished mandibular BMD and increased levels of RRR. However, this study was limited to a small patient group, which consisted of 6 edentulous female patients. In addition, BMD was estimated in the mandible in Hounsfield units (HU) using CBCT. Unfortunately, CBCT does not allow 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 (*Hua*, 2009). In this study, mandibular height measurements were carried out similar to our study on CBCT images in the regions of the mental foramina, however, the methodology was not specifically described. Unfortunately, it is impossible to compare these results with ours because of the different measurement methodologies and study populations.

In our study, we did not find a statistically significant relationship between general BMD and the amount of mandibular RRR, which corresponds

to the majority of studies published in the literature (*Kribbs* et al., 1989; *Kribbs*, 1990; *Klemetti* et al., 1993a; *Balcikonyte* et al., 2003; *Bozic* and *Hren*, 2005). However, to confirm such results, it would be necessary to perform the long-term study in dynamics of RRR by using the existing raw data as a reference point.

3.3. The relationship between the amount of mandibular residual ridge and patients` satisfaction with conventional complete dentures

In the literature there are different opinions about the effect of residual ridge amount on patients` satisfaction with conventional complete dentures, however, most authors agree that the alveolar bone volume affects the outcome of the prosthodontic treatment. But in the published studies, to characterize the amount of mandibular alveolar bone, authors have analyzed only bone height parameters, which reflect volume of bone resorption only partially (*Närhi* et al., 1997; *Pan* et al., 2010). Since the amount of bone loss is initially observed on the buccal and lingual surfaces, but only afterwards on the top of the mandibular residual ridge (*Atwood*, 1963), three-dimensional X-ray examination, such as CBCT, is required. This would allow to estimate objective amount of bone loss and its impact on patients` satisfaction with mandibular conventional complete dentures.

For our study "group A" specific selection criteria as well as new methodology was established.

Since patients` satisfaction may be associated with the ability to adapt to the dentures, all patients prior our study were using the conventional complete dentures for at least 3 years. Also to establish a specific reference point, all patients 3 years prior this study in the Prosthodontic Clinic at the Institute of Stomatology, Rīga Stradiņš University received new dentures, which were

made in the same dental laboratory. Although the opinions in the literature, whether the use of dentures at night reinforces the amount of RRR (*Campbell*, 1960; *Carlsson*, 2004) or not (*Kovacić* et al., 2010; *Kranjčić* et al., 2013), are controversial, our patients were advised not to use the conventional complete dentures during the night. Also all patients in our study had lost their last tooth at least 5 years ago, which reduced the impact of local postextraction factors on mandibular RRR (*Devlin* and *Ferguson*, 1991; *Bozic* and *Hren*, 2005) that, in turn, could cause a sudden changes in patient VAS satisfaction scores.

To clarify patients` satisfaction with complete dentures, some authors used multilevel scale where patients had to answer with 1 of 2 or more offered multiple choice questions, for example – satisfied or dissatisfied (*Garrett* et al., 1996; *De Baat* et al., 1997; *Huumonen* et al., 2012). However, most authors for assessing an immeasurable value such as satisfaction used VAS (*Awad* et al., 2003; *Pan* et al., 2010; *Nuñez* et al., 2013).

In order to determine the lowest satisfaction for each patient, in our study points from the 1st (VAS_1) and one of the worst estimated 2nd, 3rd, 4th or 5th (VAS_worst) VAS question were taken into account. This method was selected, because dissatisfaction with the use of complete dentures for each patient could be induced by different factors, for example, because of the poor stability of the mandibular denture or some soreness during the denture use.

To determine actual amount of mandibular residual ridge measurements on digital OPG as well as on CBCT images for all “group A” patients were performed.

Pan et al. (*Pan* et al., 2010) analyzed the relationship between edentulous mandibular alveolar bone height and patients` satisfaction with conventional complete dentures. To evaluate the volume of mandibular RRR for 107 patients, 5 mandibular height measurements from OPG images, which were divided into 4 different resorption classes, were performed. Patients` satisfaction with complete dentures was assessed by 100 mm VAS scale 6

months after receiving prosthodontic treatment. The results of this and our study were similar, showing no statistically significant correlation between height measurements of mandibular residual ridge and patients` satisfaction with mandibular conventional complete dentures. However, it should be noted that the time interval for each study, the patients were interviewed and VAS scores collected, i.e., 6 months and 3 years after receiving dentures, was different. That is important, because longer period of time may be associated with better adaptation and higher satisfaction scores and also possible changes in complete dentures as well as in the prosthetic field in oral cavity.

As described in previous similar studies (*Närhi* et al., 1997; *Huumonen* et al., 2012) mandibular alveolar bone height parameters were evaluated on digital OPG images. The novelty of our study was that the height measurements of the mandibular residual ridge in the same areas were performed also on sagittal CBCT images that gave the actual information about bone height, regarding longitudinal axis of the mandibular bone. This is particularly relevant when the mandible has a labial or lingual inclination, which cannot be detected on OPG images.

As a result, our study confirmed the hypothesis that there was no correlation between the height measurements of edentulous mandibular alveolar bone, measured on OPG images, and patients` satisfaction with conventional complete mandibular dentures, which in turn was when the same mandibular height measurements were performed on sagittal CBCT images.

Another novelty of our study was that the amount of mandibular RRR was assessed not only regarding the height, but also the sagittal width parameters. As a result, we found one more correlation between the width measurements of mandibular residual ridge, and patients` satisfaction with mandibular conventional complete dentures. This, in turn, suggests VAS satisfaction scores may be related directly to the bone narrowing.

Correlations in our study were mainly assessed between the amount of mandibular RRR and the worst rated question, which could be explained by the fact that patients were able to be more objective and more critical in response to specific but not general question. This tendency also appeared in *Awad* et al. study, where approximately 80% of patients responded positively about their dentures as a whole, however, the analysis of specific issues became more negative (*Awad* and *Feine*, 1998).

Until now literature shows no data about the relationship in specific time period between the amount of mandibular RRR changes and patients` satisfaction changes.

Therefore, in order to establish as possible homogeneous study "group B", specific selection criteria as well as a new methodology was developed.

Selection criteria discussed previous for the "group A" also corresponded to the "group B". In addition it should be mentioned that no patient had any relining procedures for complete mandibular dentures, since receiving them 3 years ago.

Our study showed that with a statistically significant decrease of edentulous mandibular alveolar bone height in both lateral regions of mental foramina, also statistically significant improvement in patients` assessment of the first question: "Are you satisfied with your mandibular complete denture?" occurred. Perhaps such unexpected relationship could be explained by the fact that, despite the volume reduction of mandibular residual ridge, patients during 3 years were more able to adapt to their mandibular conventional complete dentures and, in general, less unsatisfied. It should be noted that the reduction of mandibular height was relatively small (1.2 to 1.7 mm), which probably caused no discomfort and did not affect patients` VAS satisfaction scores. In addition, it should be mentioned that the measurement error in this situation was not included in the statistical calculation of the results, as it was measured separately by the method of *Dahlberg*. This, in turn, could affect the clinical

reliability of the results, showing different relationship between both discussed parameters.

Indicator that was analyzed in the literature and compared in a specific period of time, was the amount of edentulous alveolar bone for conventional complete denture users. The results clearly showed that bone height measurements after specific time period decreased, which was observed particularly in the anterior area of mandible. Various studies suggested that mandibular RRR for conventional complete denture users within 5 years is 2 times, while in the 7 and 25 years – 4 times faster than maxillary RRR (*Tallgren*, 1969; *Tallgren*, 2003; *Kovacić* et al., 2010). Also, in our study decrease of edentulous mandibular alveolar bone height for complete denture users in the time period of 3 years was observed. However, in contrast to other studies, mandibular height reduction in our study was more pronounced and statistically significant in the lateral areas, but insignificant in the mandibular midline.

The results of this study demonstrate the advantages of CBCT examination for evaluating the amount of mandibular RRR and its further relationship with patients` satisfaction with conventional complete dentures.

4. CONCLUSIONS

4.1. Dental implant planning in the anterior area of edentulous mandible on CBCT and OPG images

1. Despite greater radiation dose, CBCT rather than digital OPG examination method is indicated for dental implant planning in the anterior area of severely resorbed edentulous mandible.
2. Digital OPG as the only examination method for dental implant planning in the anterior area of severely resorbed edentulous mandible is insufficient and can result in errors in treatment planning as well as iatrogenic mistakes during surgery.

4.2. The influence of reduced general BMD on the quantitative changes of mandibular residual ridge

1. Postmenopausal women with reduced general BMD do not have diminished height of edentulous mandibular alveolar bone.
2. Buccolingual narrowing or a “knife-edge” tendency of the mandibular residual ridge is not related to reduced general BMD in postmenopausal women.

4.3. The relationship between the amount of mandibular residual ridge and patients` satisfaction with conventional complete dentures

1. Patients` satisfaction with mandibular conventional complete dentures has no relationship with the amount of mandibular RRR, as determined from digital OPG height measurements.
2. With increasing amount of mandibular RRR, regarding sagittal CBCT height and width measurements, increases patients` dissatisfaction with mandibular conventional complete dentures.
3. Despite the reduction of edentulous mandibular alveolar bone height in the lateral regions, during 3 years also patients overall dissatisfaction with mandibular conventional complete dentures decreases.

5. PRACTICAL RECOMMENDATIONS

1. Despite greater radiation dose, CBCT examination method is indicated for dental implant planning in the anterior area of severely resorbed edentulous mandible, while digital OPG as only examination method in the same situation is insufficient and can result in inappropriate treatment plan as well as iatrogenic mistakes during surgery.
2. Reduced amount of edentulous mandibular residual ridge is not clinically predisposing factor for reduced general BMD in postmenopausal women.
3. Patients with a pronounced amount of mandibular RRR can expect dissatisfaction with mandibular conventional complete dentures, although after 3 years, as a result of adaptation, such relevance may disappear.

6. SCIENTIFIC PUBLICATIONS AND PRESENTATIONS

International peer-reviewed scientific publications (2)

1. Baiba Spriņģe, Anda Slaidiņa, Una Soboļeva, Aivars Lejnieks. General bone mineral density and mandibular residual ridge resorption // The International journal of prosthodontics 2014; 27(3): 270–276.
2. Baiba Ozola, Anda Slaidiņa, Lija Lauriņa, Una Soboļeva, Aivars Lejnieks. The influence of bone mineral density and body mass index on resorption of edentulous jaws // "Stomatologija", Baltic Dental and Maxillofacial Journal, 2011; 1: 19–24.

Latvian peer-reviewed scientific publications (3)

1. Baiba Spriņģe, Anda Slaidiņa, Una Soboļeva, Aivars Lejnieks. Saistība starp bezzobu apakšžokļa rezorbciju un vispārējo kaulu minerālblīvumu // RSU Zinātniskie raksti – Internā medicīna, ķirurģija, medicīnas bāzes zinātnes, stomatoloģija, farmācija, 2011; 290–298.
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Presentations in international scientific conferences (5)

1. Dental implant planning in the edentulous mandible – OPG or CBCT? // 38th Annual Conference of European Prosthodontic Association – EPA 2014 and 21st Scientific Congress of the Turkish Prosthodontic and Implantology Association, oral presentation, Turkey, 2014
2. Samazināta vispārējā kaulu minerālblīvuma ietekme uz bezzobu apakšžokļa rezorbciju // Apvienotais Pasaules latviešu zinātnieku III kongress, poster presentation, Latvia, 2011.
3. The association between resorption af mandibular residual ridge and general bone mineral density // 4th International Conference – Advanced digital technology in head and neck reconstruction – oral presentation, Germany, 2011.
4. The impact of osteoporosis on radiomorphometric indices of the edentulous jaws // 2nd Baltic Sea Region Conference in Medical Sciences for Medical Students and Young Doctors – oral presentation, Lithuania, 2007.
5. Impact of osteoporosis on residual ridge resorbtion of edentulous jaws // 2nd Baltic Scientific Conference of Dentistry – poster presentation, Latvia, 2007.

Presentations in Latvian scientific conferences (5)

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3. Saistība starp bezzobu apakšžokļa resorbciju un vispārējo kaulu minerālblīvumu // RSU 10. zinātniskā konference – oral presentation, Latvia, 2011.
4. Bezzobu žokļu kaulu rezorbcijas saistība ar osteoporozi un ķermeņa masas indeksu // RSU rezidentu 12. zinātniski praktiskā konference – oral presentation, Latvia, 2009.
5. Osteoporozes ietekme uz bezzobu žokļu kaulu Rezorbciju // RSU 57. Medicīnas nozares studentu zinātniskā konference – oral presentation, Latvia, 2008.

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