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Evaluation of mandibular bone structure with radio-visiographic method – its usefulness for diagnostic purposes

Evaluation of the density, mineral content and bone structure of the mandible may be of great diagnostic and prognostic importance for periodontal diseases (Jeffcoat 1993; Jeffcoat 1996; von Wowern et al. 1992), dental surgery (Soikkonen et al. 1996), osteointegrative processes and particularly in prosthetic surgery and dental implantology (Arentowicz 1995; Mori et al. 1997). Though bone density measurements of the mandible and maxilla have been performed with different densitometric methods based on 2-compound X-ray absorption (von Wowern 1988), qualitative computer tomography (Ganant et al. 1996) or magnetic resonance methods, evaluation of mandibular bony structure is still more difficult. The methods allowing for objective imaging of bone structure based on histomorphological measurements (Benhamou et al. 1996; Hongo et al., 1989) are not realistic due to invasiveness, and the attempts of using visual methods so far have not produced encouraging results.

In a previously published paper (Tomaszewski 1997) the method of application of digital recording of radiological images of the mandible for the evaluation of relative density, mineral density and mandibular bone mineral content equivalent, was presented. The objective of the present study was an attempt to develop a computerised method of radiovisiographic image analysis, permitting for a relative measurement of some indices characterising the bone structure.

MATERIAL AND METHODS

The radiovisiograms performed according to methodology described previously (Tomaszewski 1997) were used for mandibular bone structure analysis. The developed application has applied flow chart of radiological bone trabecula defined by Czerwiński and Bajer (1993) based on registering subsequent densitometric curves of the analysed area. The radiological bony trabeculas (Fig. 1) are assumed those parts of densitometric diagram for which the limit of phase angle of the increase and decrease was at least 45°, and the maximum width of plateau phase expressed as percentage of the sum of the width of phases did not exceed 300%. To eliminate the influence of small deviations in grey intensity, application of averaging the densitometric curves prior to analysis as well as an option of looking for the trabeculas on the verges of the analysed area was introduced.

Fig. 1. Graphic definition of trabeculas on the microdensitometric curve

The programme which was developed in co-operation with IT Programmers of the Jagiellonian University: R. Wrona and A. Bak, based on measurements of radiological trabeculas defined in the above described way, allows for calculation of the following indices: 1) average number of trabeculas per 1 mm^2 of the analysed area (STN), 2) volume of the trabeculas expressed as percentage of the volume of the total radiogram (STV), 3) density expressed in percentage of the area covered with trabeculas (STD), 4) number of trabeculas per 1 mm of line (STL), 5) width of trabeculas in mm (STW), 6) height of trabeculas expressed as percentage of the difference between the lowest and highest values of the densitometric measurement of the analysed image (STH), 7) the area of trabeculas in relation to total analysed area (A).

Besides the listed numerical indices the application allows for the graphic presentation of the result of radiovisiogram analysis in the form of original images of the area, the map of trabeculas on the analysed area, densitometric diagram of individual analysed lines and the three-dimensional densitometric diagram of the analysed area (Fig. 2).

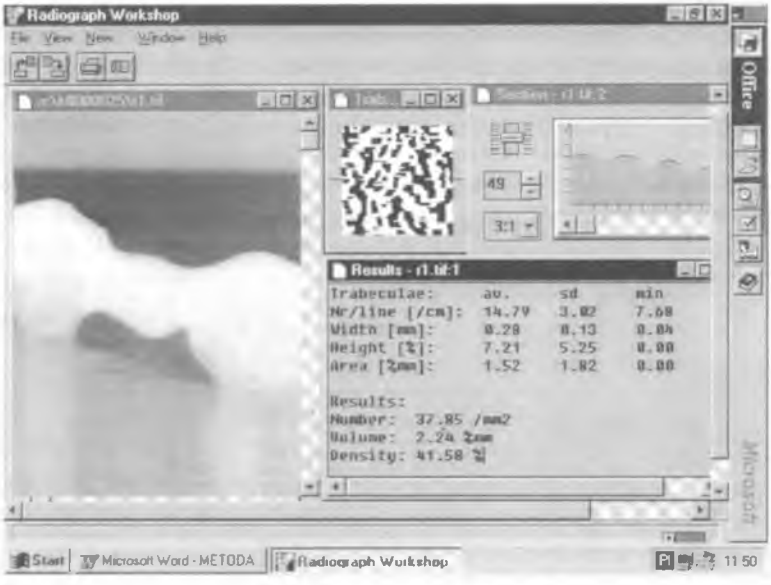

Fig. 2. Windows Radiograph Workshop program – results of bone structure analysis

Repeatability of the results was assessed by taking 21 radiovisiographs with Trophy camera and by applying two kinds of sensors: the first of the size 27.5 x 18.2 mm and line definition of 8 pairs of line/mm, and the second of size 30x30 mm and line definition of 12 pairs of line/mm. The results expressed by the obtained coefficients of variation are presented in Table 1.

Table 1. Precision of measurements of mandibular bone structure indices on the basis of 21 RVG images of mandible preparations

Indices	Sensor I			Sensor II		
	X	SD	CV%	X	SD	CV%
N. of trabeculas/mm^2	29.78	0.82	2.77	23.13	0.83	3.56
Density	39.68	1.56	3.92	28.62	0.60	4.08
N. of trabeculas/1 mm	1.71	0.05	2.84	1.82	0.06	3.48
Width (mm)	0.23	0.01	3.60	0.23	0.01	3.60
Height (%)	4.68	0.22	4.79	4.06	0.19	4.68
Area (%mm^2)	0.88	0.06	6.84	0.97	0.07	7.01

The obtained results indicate that the computer application allows for reliable measurement of the registered parameters of the radiological trabeculas structure, and the obtained coefficient of variation of the radiological trabecular structure and of the anatomic samples of the mandible does not exceed 5% in principle.

Clinical tests were performed in 240 persons, including 110 patients treated in the Department of Dental and Maxillofacial Surgery and 130 patients from the Osteoporosis Clinic of the Institute of Rural Medicine. The reviewed group included 160 women and 80 men whose average age was 54.4 + 14.0 and 50.3 + 15.4, respectively. Based on supplementary examinations performed in the Osteoporosis Clinic of the Institute of Rural Medicine by Dr M. Jabłoński and Dr M. Gorzelak, osteoporosis was diagnosed in 130 patients. Additionally to sex, age and osteoporosis phenomena, the analysis of the mandible bone structure evaluation results also considered the presence or absence of teeth in the location of the radiovisiogram taken and the level of alveolar process atrophy in the respective group.

RESULTS

Two radiovisiograms area analysed by the prepared application, evaluating the elements of bone tissue structure (Fig. 3 and 4) are presented.

In the radiovisiogram of a patient aged 34 years, fine-trabecular structure dominates whereas the analysis of a patient aged 71 years adiovisiogram reveals the image of smaller density of trabeculas. The results of mandibular bone structure analysis in relation to age and sex of the patients are presented in Table 2.

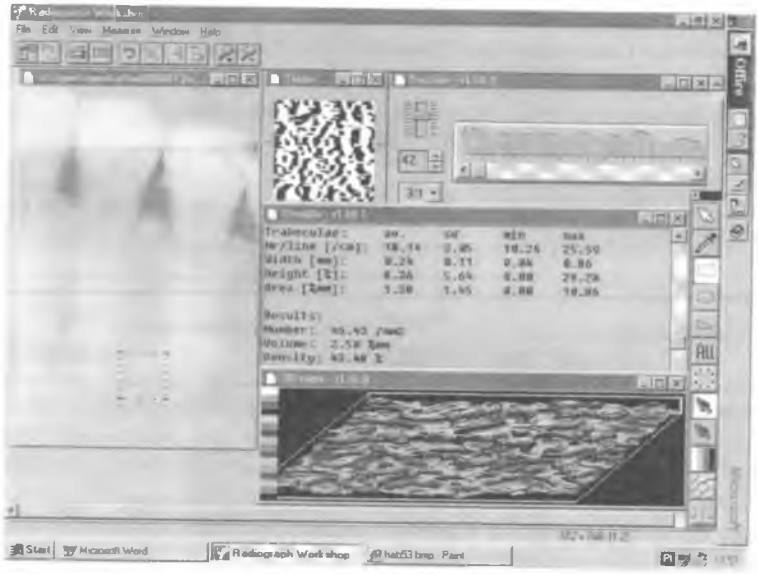

Fig. 3. Radiovisiogram of patient M.D. aged 34 years – analysis of structure

Fig. 4. Radiovisiogram of patient K.W. aged 71 years – analysis of structure

Table 2. Indices of mandible bone structure: mean radiological trabeculas number per 1 mm^2 (STN), trabeculas volume (STV), density expressed as % of area (STD), number of trabeculas on 1 mm of line (STL), trabeculas width in mm (STW), trabeculas height (STH) and area of trabeculas (STA) in groups divided according to sex and age

	Indices of structure	Age groups				Total
		<30	31-40	41-50	>50	
Women	STN (/mm^2)	47.60	41.80*	41.19*	40.80*	42.18
	STV (%)	2.07	1.67*	1.90	1.84	1.86
	STD (%)	42.93	40.82*	40.69*	40.13*	40.85
	STL (/mm)	1.96	1.77*	1.72*	1.74*	1.78
	STW (mm)	0.22	0.23	0.24	0.24*	0.24
	STH (%)	6.31	5.48	6.01	5.93	5.94
	STA	1.11	0.96	1.16	1.12	1.11
Men	STN (/mm^2)	48.15	44.80	43.97	41.30*	44.45
	STV (%)	2.15	2.01	1.92	1.77	1.96
	STD (%)	42.82	41.50	41.70	40.27*	41.55
	STL (/mm)	1.96	1.86	1.79	1.70*	1.82
	STW (mm)	0.22	0.23	0.24	0.24	0.23
	STH (%)	6.68	6.43	6.33	5.96	6.34
	STA	1.14	1.11	1.22	1.08	1.14
Together	STN (/mm^2)	47.83	43.00*	42.13*	40.92*	42.93
	STV (%)	2.10	2.20*	1.91	1.82*	1.89
	STD (%)	42.88	41.09*	41.03*	40.16*	41.08
	STL (/mm)	1.96	1.81*	1.74*	1.73*	1.79
	STW (mm)	0.22	0.23	0.24*	0.23	0.23
	STH (%)	6.47	5.86	6.12	5.94	6.07
	STA	1.13	1.02	1.18	1.11	1.12

* Significant difference in relation to the first age group ($p<0.05$).

It appears that with age, there is a significant decrease in the average number of trabeculas per 1 mm of the analysed area (STN) of the density expressed in percentage of surface covered with the trabeculas (STD) and the average number of trabeculas per 1 mm of lines (STL). However, the increases in average width of radiological trabecula (STW) have been observed.

In groups differentiated according to sex with similar conditions of changes influenced by age, no significant differences between men and women were reported. However, Figures 5 and 6 indicate that significant changes in the mandible bone structure result from osteoporosis.

The results of the radiological tests of mandibular bone structure in patients with osteoporosis and without diagnosed osteoporosis are presented in Table 3.

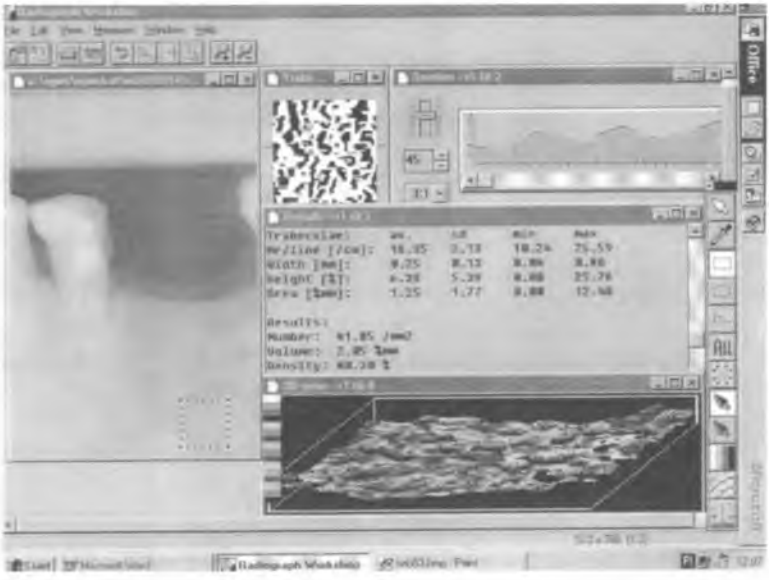

Fig. 5. Radiovisiogram of patient M.H. aged 70 years without osteoporosis – analysis of structure

Fig. 6. Radiovisiogram of patient Z.K. aged 73 years with osteoporosis – analysis of structure

Table 3. Indices of mandible bone structure: mean radiological trabeculas number per 1 mm² (STN), trabeculas volume (STV), density expressed as % of area (STD), number of trabeculas on 1 mm of line (STL), trabeculas width in mm (STW), trabeculas height (STH) and area of trabeculas (STA) in groups with and without osteoporosis

Indices of structure	Group		Difference
	without osteoporosis	with osteoporosis	(P<)
STN (/mm²)	46.68 ± 6.44	39.77 ± 6.25	0.0001
STV (%)	1.98+ 0.64	1.82 ± 0.62	0.05
STD (%)	42.84 ± 2.68	39.60 ± 3.65	0.0001
STL (/mm)	1.93± 0.31	1.67± 0.28	0.0001
STW (mm)	0.22 ± 0.03	0.24 ± 0.03	0.0001
STH (%)	6.25 ± 1.77	5.93 ± 1.61	ns
STA	1.09± 040	1.14± 0.45	ns

The analysis of radiovisiographic indices of the mandible bone structure showed that both for women and men there are significant differences between groups of patients with osteoporosis and patients without clinical and laboratory characteristics of the disease. In the subgroup of patients with osteoporosis, a significantly smaller average number of radiological trabeculas per 1 mm² of the analysed area (STN), their average density (STD) and average number of trabeculas per 1 mm of analysed line (STL) were noticed. However, significantly bigger was the average width of radiological trabeculas seen in the radiovisiograph (STW). The differences in the trabeculas volume index (STV) appear slightly smaller ($p<0.05$). However, no significant differences in the relative radiological trabeculas height (STH) and the trabeculas area index (STA) were noticed.

Graphic presentation of the difference between the groups of patients without osteoporosis and with osteoporosis is shown in Figures 7-10.

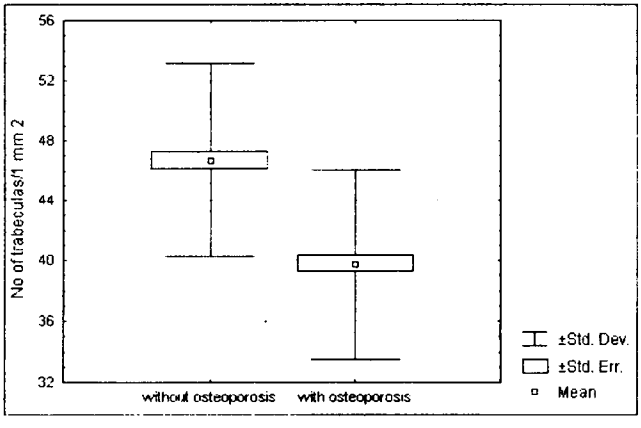

Fig. 7. Mean number of radiological trabeculas per 1 mm² of area in patients with and without osteoporosis

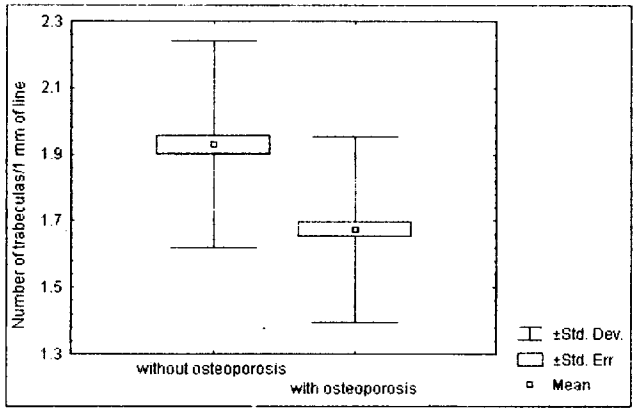

Fig. 8. Mean number of radiological trabeculas per 1 mm of analysed line in patients with and without osteoporosis

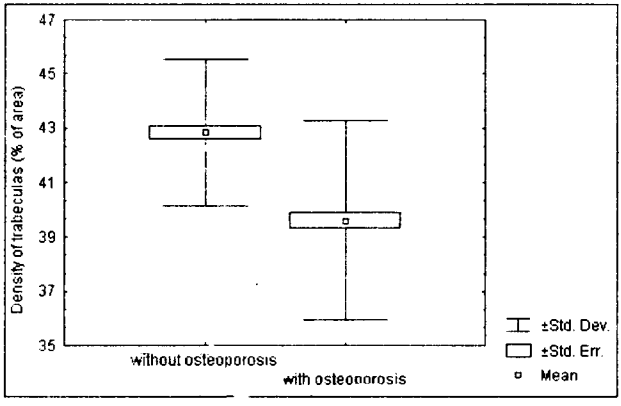

Fig. 9. Mean density of radiological trabeculas in patients with and without osteoporosis

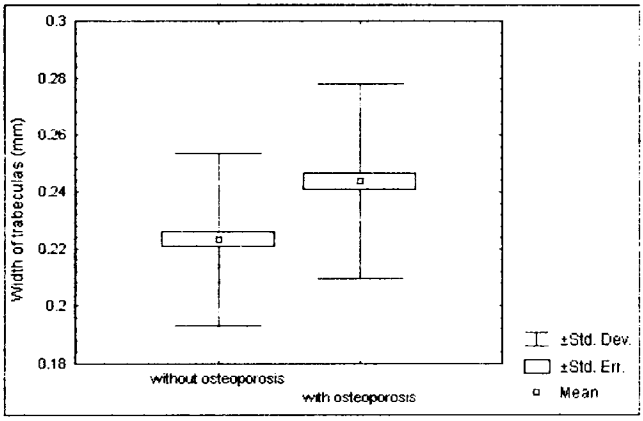

Fig. 10. Mean width of radiological trabeculas in patients with and without osteoporosis

DISCUSSION

The investigations of non-invasive evaluation of bone tissue structure *in vivo* carried out in several centres are based mainly on mathematical analysis of CT or NMR images (G a n a n t et al. 1996; G o r d o n et al. 1997). The present paper while making use of the earlier experiments of C z e r w i ń s k i et al. (Baron et al. 1984, C z e r w i ń s k i et al. 1990) on determining the trabecula radiologically in the classic X-ray picture of long bones, attempted the computer analysis of digitally recorded radiovisiographic images of the mandible. It appears that the developed Radiograph Workshop programme (RWP) allows for relational quantitative description of bony tissue structure of the mandible, as well as for registration of changes going on in physiological and pathological conditions. Having found no changes in sex-related structural indices, it was concluded that with the age the trabecular width increases whereas the relations between their amount and density deteriorate. H o n g o and al. (1989) obtained similar results in the morphological test of mandible bone specimens.

Particularly significant differences were disclosed between the group of patients diagnosed with osteoporosis and without osteoporosis. In the group with osteoporosis a considerable decrease in the number of trabeculas per 1 mm, a significant decrease in the average number of trabeculas per 1 mm of the analysed line, as well as a significant increase in the average width of radiological trabeculas, in comparison to the group without osteoporosis have been observed. With the observed changes in the mineral density of the mandible (T o m a s z e w s k i 1997), this fact also supports the opinion that generalised osteoporosis weakens the mandible bone tissue and is a significant factor influencing the condition of teeth. It seems that the developed programme of computer analysis of mandible bone radiovisiographic image opens new, simple and friendly to patients diagnostic opportunities useful not only in early detection of osteoporotic changes but also allowing for prospective evaluation of dentition and osteointegrative processes.

CONCLUSIONS

1. Computer analysis of radiovisiograms taken in the developed standard condition with application of the Radiograph Workshop program allows for relatively detailed and reliable evaluation of the mandible bone tissue structure.

2. Radiological mandibular bone structure shows minor differences related to sex and age of the patients.

3. Osteoporosis diagnosed in the clinical tests and densitometric tests of antebrachial bones is accompanied by significant changes in the mandibular bone structure. In patients affected by the disease a decrease in the number and density of trabeculas as well as an increase in mean radiological trabecular width was observed.

4. Standardised radiovisiographic tests of the mandible supplemented with computer analysis of the structure with application of the Radiograph Workshop program may be helpful in diagnosing changes of the mandibular bone.

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SUMMARY

The noninvasive assessment of the mandible bone structure can be, beside the indices of mineral density and content of mineral elements, the source of valuable information of diagnostic and prognostic importance. The presented examinations aimed at working out a computer program of radiovisiographic picture analysis of the mandible bone, which, on the basis of radiological trabecula algorithm, would enable finding out parameters determining mean number of trabeculas per 1 mm^2 of the analysed area, density expressed in percentage of the area covered with trabeculas, mean width and height of radiological trabeculas, and several calculable derivative indices. On the basis of the above mentioned program there was made an analysis of radiovisiograms of 130 patients with diagnosed osteoporosis and of 110 patients without osteoporosis, treated in the Department and Clinic of Dental and Maxillofacial Surgery, Medical University of Lublin. Slight differences conditioned by sex and age of the patients as well as significant changes in structural indices in patients with generalized osteoporosis were found.

The performed tests show that standardized radiovisiographic examinations of mandibular bones completed with computer structure analysis by Radiograph Workshop program can be helpful in diagnostics of osseous changes in mandibular bones.

Diagnostyczna użyteczność zastosowania metody radiowizjograficznej w ocenie struktury kości żuchwy

Bezinwazyjna ocena struktury kości narządu żucia może być, obok wskaźników gęstości mineralnej i zawartości składników mineralnych w kości, źródłem cennych informacji o znaczeniu diagnostycznym i prognostycznym. Przedmiotem prezentowanych badań było opracowanie komputerowego programu analizy obrazu radiowizjograficznego kości żuchwy, który w oparciu o algorytm beleczki radiologicznej umożliwiłby wyznaczenie parametrów określających średnią liczby beleczek na 1 mm^2 analizowanego obszaru, gęstość wyrażoną w % powierzchni pokrytej beleczkami, średnią szerokość i wysokość beleczek radiologicznych oraz kilka wyliczalnych wskaźników pochodnych. Na podstawie opracowanego programu przeprowadzono analizę radiowizjogramów 130 pacjentów z rozpoznaną osteoporozą oraz 110 chorych bez osteoporozy, leczonych w Katedrze i Klinice Chirurgii Stomatologicznej i Szczękowo-Twarzowej AM w Lublinie, stwierdzając nieznaczne różnice uwarunkowane płcią i wiekiem badanych oraz istotne zmiany we wskaźnikach struktury u chorych z uogólnioną osteoporozą.

Przeprowadzone badania wskazują na to, że standaryzowane badania radiowizjograficzne kości żuchwy, uzupełnione komputerową analizą struktury za pomocą opracowanego programu Radiograph Workshop, mogą być pomocne w diagnostyce zmian kostnych narządu żucia.