VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 70, No. 4, pp. 272–281

ISSN 0015–5659
www.fm.viamedica.pl

Mandibular inferior cortex width may serve as a prognostic osteoporosis index in Polish patients

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[Received 25 March 2011; Accepted 5 August 2011]

Background: *Panoramic radiographs are increasingly considered as a screening tool in the search for osteopaenia and osteoporosis. No information on normal ranges of radiographic parameters of the inferior cortex (IC) in Polish population has been found in literature; therefore, the objective of the study was to determine normal ranges of mandibular inferior cortex width on panoramic radiographs and to examine the influence of gender and age on these parameters.*

Material and methods: *The material consisted of 877 digital panoramic radiographs taken of patients aged 20 to 95 years (mean 48.69 years), including 467 females and 410 males. Mandibular inferior cortex width at the mental foramina was estimated, and the obtained results were subjected to statistical analysis.*

Results: *It was found that IC and mental index (MI) values in the studied group of Polish patients depended on age. As far as gender is considered, IC and MI were higher in males. When age and gender were discussed simultaneously, the highest values of IC and MI were observed in age group 30–39 years in both genders, followed by a gradual decrease with age, but this decrease was more pronounced in females.*

Conclusions: *The elaborated norms of panoramic radiomorphometric parameters in Polish patients may serve as a source of comparison for radiological and clinical applications.* (Folia Morphol 2011; 70, 4: 272–281)

Key words: panoramic radiographs, mandibular inferior cortex, radiomorphometric indices, osteoporosis prediction, Polish population

INTRODUCTION

Radiographs are widely used in dentomaxillofacial imaging, and their diagnostic efficacy has been well documented. Most frequently, dental X-rays are prescribed when pathology is suggested. However, panoramic radiographs, presenting tomographic images of both dental arches with alveolar processes, mandible, and a considerable part of maxilla, are increasingly considered as a screening tool in the search for osteopaenia and osteoporosis. Densitometric screening of all postmenopausal women is not cost-effective, and the sensitivity of bone densitometry is relatively low. A cheap and effective method of selection of a group of patients referred for densitometry is sought, and panoramic radiographs serve as a source of evaluation of radiomorphomet-

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ric parameters and indices [6]. Dentists are privileged in screening for osteoporosis, because every year a large part of the elderly population visits their practices. It is estimated that dental radiographs comprise 32% of all X-rays taken annually in the United Kingdom, including 2 million panoramic radiographs in the National Health Service in England and Wales alone [4]. In Japan 10 million panoramic X-rays are taken in 65,000 dental practices, and about one-third of the examined patients are persons aged 45–65 years [19].

Various panoramic radiomorphometric indices have been described and used [1, 2, 4, 5, 7, 8, 12, 13, 14–20]. One of the most commonly applied radiomorphometric parameters is estimation of the width of the inferior mandibular cortex at the mental foramen in the line passing through this foramen perpendicular to the inferior margin of the mandible [19], named the inferior cortex (IC). Some authors describe this parameter as the mental index (MI) or cortical width (CW) [20]. According to other authors, the MI or cortical index (CI) is a mean value of the measurements of the inferior cortical width at both sides of the mandible [3, 4, 13, 20]. In literature other abbreviations for this index can be found, i.e. mandibular cortex width (MCW) or mandibular cortical thickness (MCT) [8, 17]. Measurement of the IC (MI) is performed in the vertical plane on panoramic X-rays; therefore, it is not considerably affected by positioning mistakes during radiography — the mean variability of these measurements is only 2% [4].

No information on normal ranges of IC in the Polish population has been found in literature; therefore, the objective of the study was to determine normal ranges of mandibular IC width on panoramic radiographs and to examine the influence of gender and age on these parameters.

MATERIAL AND METHODS

The material consisted of 877 digital panoramic radiographs taken in patients aged 20 to 95 years (mean 48.69 years), including 467 females and 410 males, not suffering from chronic infections that could affect bone tissue. All the radiographs were taken by means of Proscan (Planmeca, Finland) panoramic X-ray and Dürr Dental (Germany) digital radiography system. Only good quality radiographs of adult patients were selected from the digital archives of the Department of Dental and Maxillofacial Radiology of the Medical University of Lublin, Poland. All examinations were prescribed due to clinical indications, i.e. none of them was taken solely for the purposes of this study.

Subsequently, the radiographs were exported from the digital radiography DBSWIN v. 3.2.2-E software (Dürr Dental) as bitmap files to Emago® ver. 3.42 software (Oral Diagnostic Systems, ACTA, Holland), which is dedicated to advanced analysis of digital dental radiographs. After image calibration (using a tool of known length and Endo Length option) the thickness of the mandibular inferior cortex at the mental foramen (IC) was measured at both sides of the mandible. Then the so-called MI was calculated as a mean value of the IC results for the right and left sides of the mandible.

The mean, minimum, and maximum values of the parameters and indices were analysed regarding age groups (20–29 years; 30–39 years; … ; 60–69 years; over 70 years of age) as well as taking into account gender — in the total group as well as within the age groups.

Statistical analysis was performed using Statistica software package for Windows (StatSoft Media, licence no. BXXP807E041622FA-R). Descriptive statistics was used in order to analyse the mean, median, maximum, and minimum values of the inferior mandibular cortex in total as well as regarding gender, age, and both variables simultaneously. Shapiro-Wilk test was used in order to determine the distribution of the obtained data, and depending on its results U Mann-Whitney test or Student's t test were used to study the differences between the groups regarding gender. Spearman's coefficient of ranks was applied to analyse correlations between variables.

RESULTS

Mean values of panoramic radiographic indices in the studied population are presented in Table 1. Age correlated negatively with IC on both sides and MI ($r = -0.3464$ on the right side, and $r = -0.4355$ on the left) (Table 2, Figs. 1–6).

Mean IC width equalled 3.23 ± 0.79 mm on the right and 3.19 ± 0.8 mm on the left. Mean MI index was 3.21 ± 0.76 mm. Mean width of the inferior mandibular cortex (IC as well MI) was lower in females than in males, and this difference was statistically significant (in all cases $p < 0.01$) (Table 3). For the width of the inferior cortex of the mandible (IC), an age-related decrease was evident. IC was lower overall in females than in males (mean, minimum, maximum values). This difference was striking in the oldest age groups (Tables 4, 5). The high-

Table 1. Descriptive statistics of panoramic radiomorphometric parameters for the whole group

Variable	Number	Mean	Median	Minimum	Maximum	Standard deviation
Inferior cortex right side	877	3.23	3.25	1.08	6.17	0.8
Inferior cortex left side	877	3.19	3.25	1.0	5.5	0.8
Mental index	877	3.21	3.25	1.04	5.58	0.76

Table 2. Correlations between age and panoramic radiomorphometric indices (Spearman's correlation coefficients) (statistically significant correlations marked with an asterisk)

Pair of variables	Number	R Spearman's coefficient	Statistics t(N-2) value	Probability
Age and inferior cortex right side	877	–0.304826	–9.46745	0.00*
Age and inferior cortex left side	877	–0.418914	–13.6468	0.00*
Age and mental index	877	–0.378927	–12.1121	0.00*

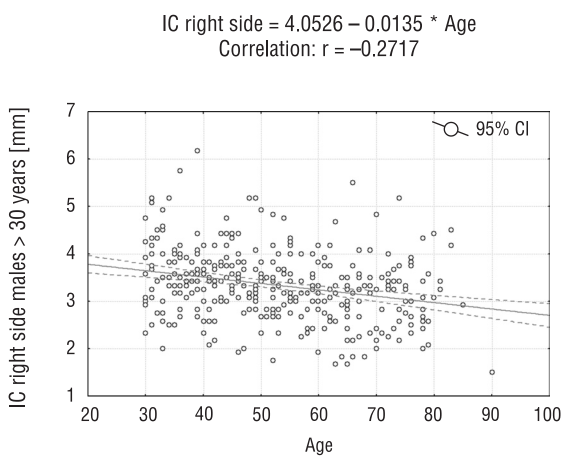

Figure 1. Correlation between age and inferior cortex (IC) right side values in males aged over 30 years; CI — confidence interval.

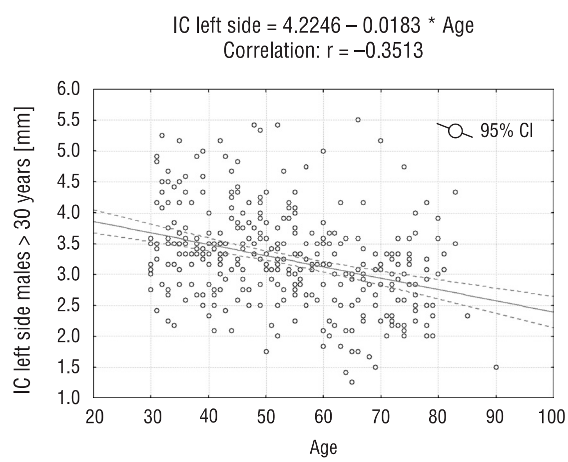

Figure 3. Correlation between age and inferior cortex (IC) left side values in males aged over 30 years; CI — confidence interval.

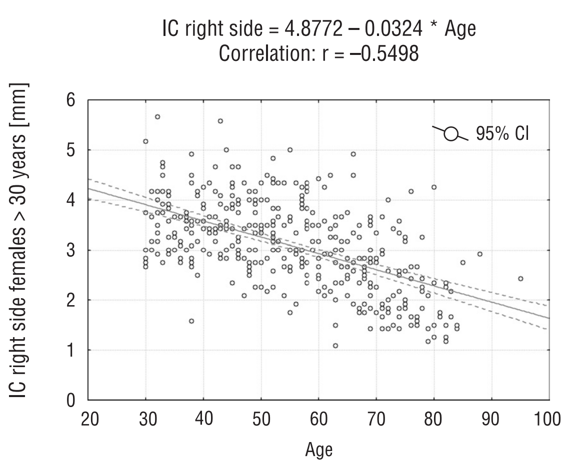

Figure 2. Correlation between age and inferior cortex (IC) right side values in females aged over 30 years; CI — confidence interval.

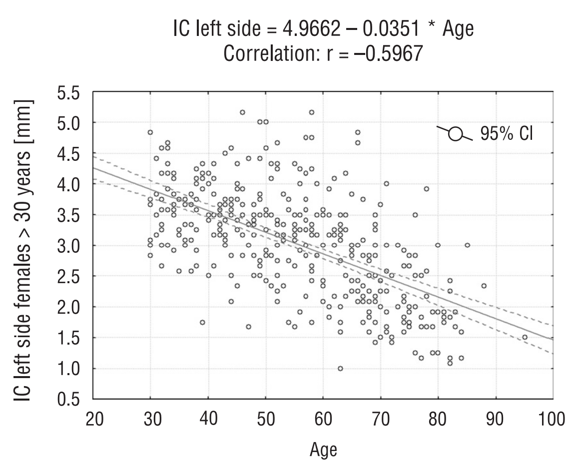

Figure 4. Correlation between age and inferior cortex (IC) left side values in females aged over 30 years; CI — confidence interval.

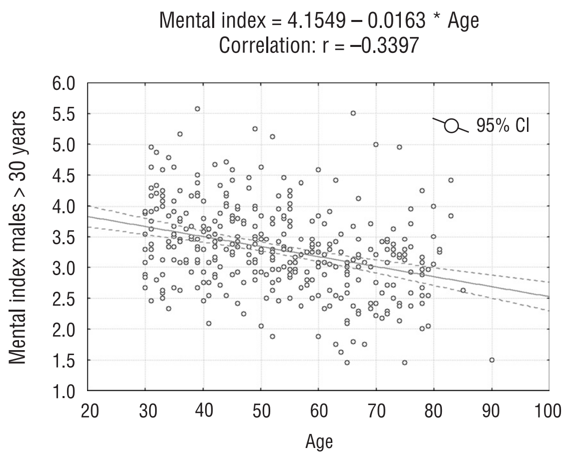

Figure 5. Correlation between age and mental index values in males aged over 30 years; CI — confidence interval.

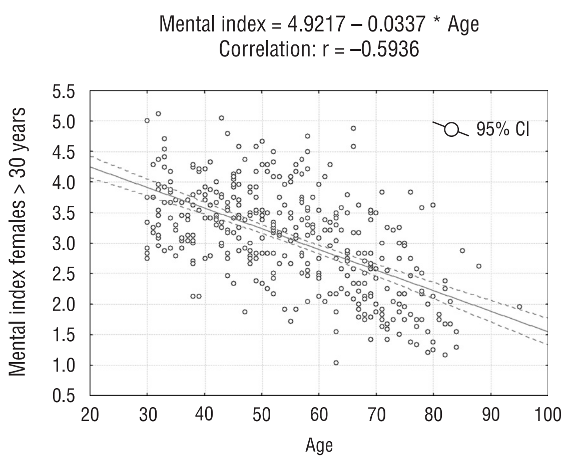

Figure 6. Correlation between age and mental index values in females aged over 30 years; CI — confidence interval.

est mean, minimum, and maximum values were observed in adults aged 30–39 years, then the values decreased steadily. In addition, the MI index (being the mean value of IC parameters determined on both sides of the mandible) consequently followed the same pattern of decrease. In the oldest age group mean MI was 2.99 mm in males and 2.17 mm in females (Table 6). Minimal observed IC values were 1.08 mm in a female patient aged 65 years and 1.5 mm in an edentulous male aged 90 years. Mean, minimal, and maximal IC values in the total group and separately in females and males are presented in Figures 7–15.

DISCUSSION

It is believed that the width of the inferior mandibular cortex in females rises dramatically in the second decade, and then it is more or less constant until the sixth decade of life, while after 60 years of age it undergoes a rapid decrease and then again remains at a constant but low level in the seventh decade of life [16, 18]. This study was not prospective; nevertheless, the general tendency in mean IC width was as follows — it was highest in patients aged 30–39 years, and then it decreased in the consecutive age groups. This trend can be explained by the probable effect of the dramatic decrease of oestrogen levels in older females.

In another study Knezović Zlatarić et al. [12] determined MI in 96 women aged 48 to 86 years and 40 men aged 56 to 84 years. They observed a general decrease of these indices up to 75 years of age, more substantial in older females. In our material there were 136 patients aged over 70 years, including 66 patients over 75 years, but no dramatic decrease of MI index was noted over this age limit.

Numeral MI or IC values determined by various authors differ due to the fact that panoramic machines vary in magnification coefficients [15]. Therefore, in our material the digital radiographs were calibrated, and it was taken into account that the measurements in the vertical plane are less prone to

Table 3. Differences in panoramic radiomorphometric indices between females and males — U Mann-Whitney test results (statistically significant differences marked with an asterisk)

Variable	Gender	Number	Mean	Standard deviation	U Mann-Whitney test results	Probability
Inferior cortex right side	Females	467	3.133298	0.828978	3.523595	0.000*
	Males	410	3.338415	0.740207		
Inferior cortex left side	Females	467	3.098858	0.823030	2.731819	0.006*
	Males	410	3.298171	0.765960		
Mental index	Females	467	3.116078	0.791513	3.117431	0.002*
	Males	410	3.318293	0.697803		

Table 4. Descriptive statistics of the right side inferior cortex parameter regarding age and gender

Age group	Number	Mean	Standard deviation	Minimum	Maximum
Total					
20–29 years	158	3.329114	0.613440	2.083333	5.750000
30–39 years	149	3.583333	0.738653	1.583333	6.166667
40–49 years	154	3.487013	0.651316	1.916667	5.583333
50–59 years	148	3.336149	0.679540	1.750000	5.000000
60–69 years	132	2.912247	0.775015	1.083333	5.500000
> 70 years	136	2.624387	0.890334	1.166667	5.166667
Males					
20–29 years	62	3.393817	0.627825	2.166667	5.333333
30–39 years	81	3.632716	0.770076	2.000000	6.166667
40–49 years	75	3.454444	0.657210	1.916667	5.166667
50–59 years	70	3.294048	0.633492	1.750000	4.916667
60–69 years	58	3.070402	0.757966	1.666667	5.500000
> 70 years	64	3.109375	0.735512	1.500000	5.166667
Females					
20–29 years	96	3.287326	0.603580	2.083333	5.750000
30–39 years	68	3.524510	0.700488	1.583333	5.666667
40–49 years	79	3.517932	0.648342	2.083333	5.583333
50–59 years	78	3.373932	0.720342	1.750000	5.000000
60–69 years	74	2.788288	0.770606	1.083333	4.916667
> 70 years	72	2.230324	0.752993	1.166667	4.250000

Table 5. Descriptive statistics of the left side inferior cortex parameter regarding age and gender

Age group	Number	Mean	Standard deviation	Minimum	Maximum
Total					
20–29 years	158	3.427215	0.592007	2.083333	5.416667
30–39 years	149	3.571588	0.670458	1.750000	5.250000
40–49 years	154	3.476190	0.665352	1.666667	5.416667
50–59 years	148	3.279279	0.711161	1.666667	5.416667
60–69 years	132	2.781566	0.793950	1.000000	5.500000
> 70 years	136	2.484681	0.788954	1.083333	5.166667
Males					
20–29 years	62	3.555108	0.656504	2.083333	5.416667
30–39 years	81	3.584362	0.717162	2.166667	5.250000
40–49 years	75	3.495556	0.718024	2.083333	5.416667
50–59 years	70	3.257143	0.646548	1.750000	5.416667
60–69 years	58	2.846264	0.825076	1.250000	5.500000
> 70 years	64	2.910156	0.706842	1.500000	5.166667
Females					
20–29 years	96	3.344618	0.533747	2.250000	4.833333
30–39 years	68	3.556373	0.615149	1.750000	4.833333
40–49 years	79	3.457806	0.615255	1.666667	5.166667
50–59 years	78	3.299145	0.768170	1.666667	5.166667
60–69 years	74	2.730856	0.770527	1.000000	4.833333
> 70 years	72	2.106481	0.657243	1.083333	4.000000

Table 6. Descriptive statistics of the mental index in age groups and regarding gender

Age group	Number	Mean	Standard deviation	Minimum	Maximum
Total					
20–29 years	158	3.378165	0.540585	2.125000	5.291667
30–39 years	149	3.577461	0.651287	2.125000	5.583333
40–49 years	154	3.481602	0.597383	1.875000	5.250000
50–59 years	148	3.307714	0.650464	1.708333	5.125000
60–69 years	132	2.846907	0.755168	1.041667	5.500000
> 70 years	136	2.554534	0.801258	1.166667	5.000000
Males					
20–29 years	62	3.474462	0.583351	2.125000	5.291667
30–39 years	81	3.608539	0.678018	2.333333	5.583333
40–49 years	75	3.475000	0.616420	2.083333	5.250000
50–59 years	70	3.275595	0.598840	1.875000	5.125000
60–69 years	58	2.958333	0.752473	1.458333	5.500000
> 70 years	64	2.988932	0.709567	1.458333	5.000000
Females					
20–29 years	96	3.315972	0.504464	2.375000	5.166667
30–39 years	68	3.540441	0.620902	2.125000	5.125000
40–49 years	79	3.487869	0.582614	1.875000	5.041667
50–59 years	78	3.336538	0.696141	1.708333	4.750000
60–69 years	74	2.759572	0.750778	1.041667	4.875000
> 70 years	72	2.168403	0.672816	1.166667	3.833333

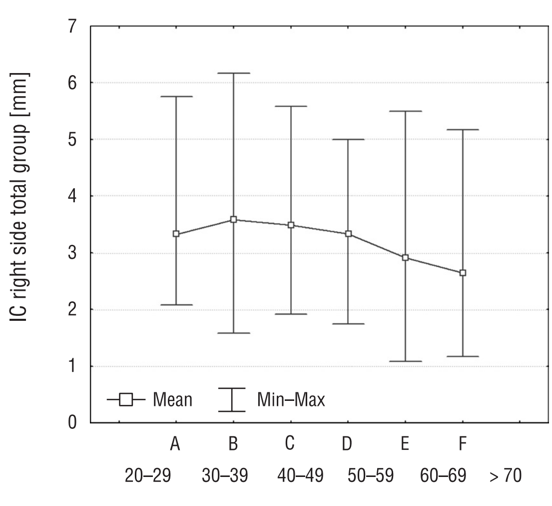

Figure 7. Box-plot chart of inferior cortex (IC) right side values of all examined patients according to age groups.

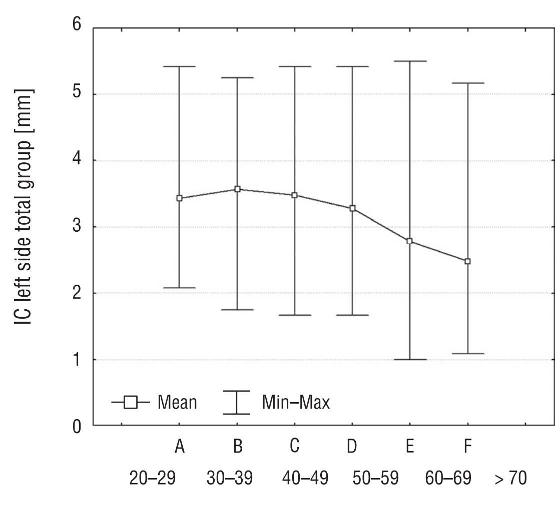

Figure 8. Box-plot chart of inferior cortex (IC) left side values of all examined patients according to age groups.

distortion on panoramic X-rays than measurements in the horizontal plane.

Another source of differences in inferior CW of the mandible may result from racial background [19]. For example, in nine Japanese female patients with vertebral fractures examined by Taguchi et al. [18] mean MI equalled 3.7 ± 0.9 mm, while in 55 controls it was 3.9 ± 1.4 mm. In another study presented by the same research team MI equalled 4 ± 1.0 mm in postmenopausal patients [16].

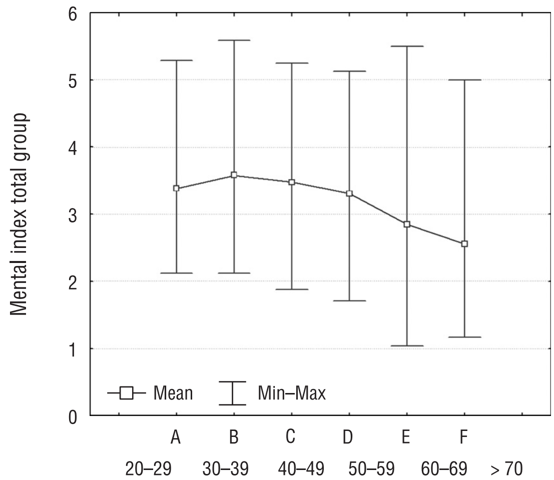

Figure 9. Box-plot chart of mental index values of all examined patients according to age groups.

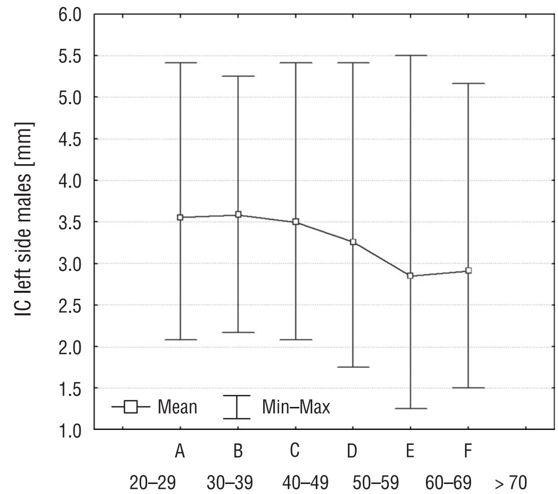

Figure 11. Box-plot chart of inferior cortex (IC) left side values in males according to age groups.

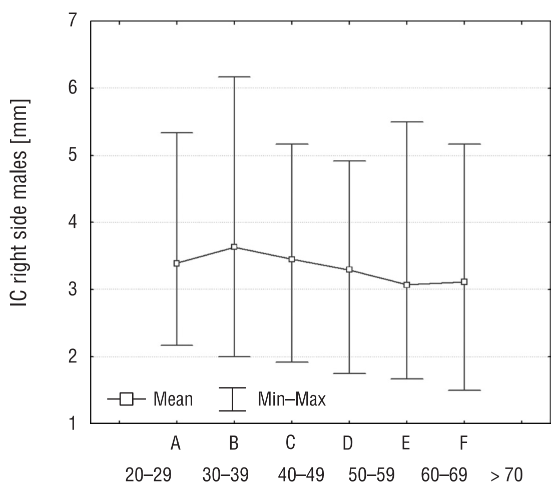

Figure 10. Box-plot chart of confidence interval (IC) right side values in males according to age groups.

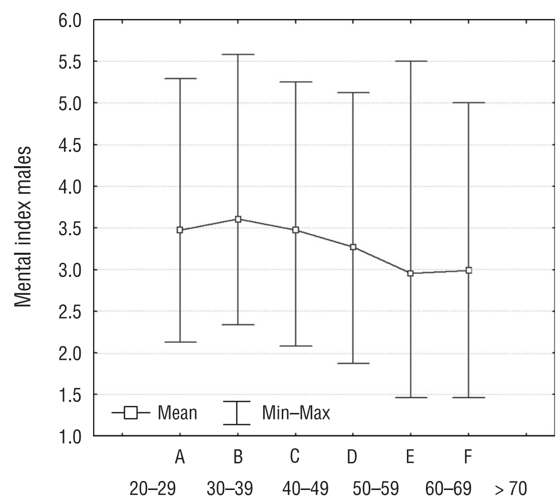

Figure 12. Box-plot chart of mental index values in males according to age groups.

In 27 osteoporotic Turkish patients [20] mean MI was 4.48 ± 1.24 mm, while in 21 healthy controls aged 40 to 64 it was 5.04 ± 1.01 mm. In our material, in females aged 40–49 years MI equalled 3.48 ± 0.58 mm and in 50–59 year old women it was 3.34 ± 0.7 mm. In 2005 Dutra et al. [2] carried out studies on relationships between radiomorphometric indices and gender and age of 312 female patients aged 40–79 years, divided into age groups with a 10 year span, as in our study. These authors determined IC bilaterally (described in the quoted paper as MI) and found a mean value of 3.94 ± 0.05 mm on the right and 4.00 ± 0.06 mm on the left side of the mandible, with no statistically significant difference between the sides. In a Turkish population studied by Gulsahi et al. [7] MI ranged from 4.92 ± 0.32 mm in patients with intact internal border of inferior mandibular cortex down to 4.24 ± 0.52 mm in patients with severe resorption of this anatomical structure, evaluated according to the mandibular cortical index (MCI) classification first described by Klemetti and Kolmakov [11].

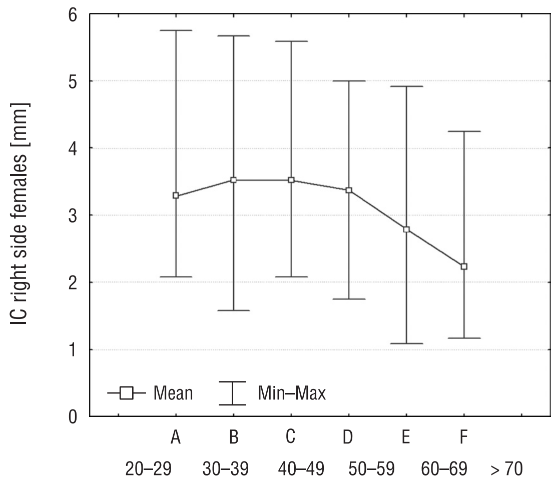

Figure 13. Box-plot chart of inferior cortex (IC) right side values in females according to age groups.

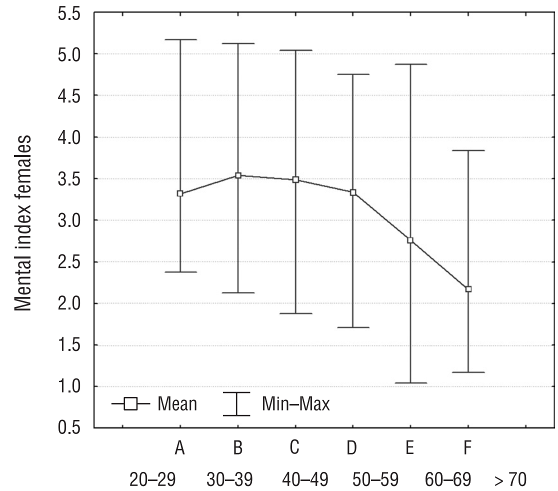

Figure 15. Box-plot chart of mental index values in females according to age groups.

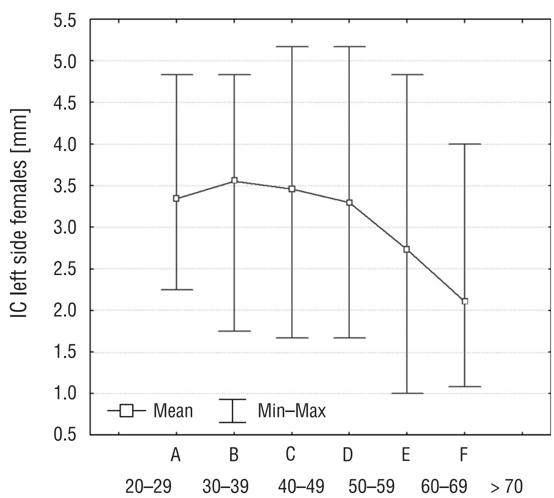

Figure 14. Box-plot chart of inferior cortex (IC) left side values in females according to age groups.

At the same time, it is also underlined that IC may reflect peak bone mass gained in earlier stages of life rather than bone metabolism during menopause [19]. This may be the reason why, in our material, maximum observed IC values were as high as 6.17 mm in a 39-year-old male and 5.75 mm in a 21-year-old female.

Ledgerton et al. [13] showed a strong negative correlation of MI index with age until 60 years, when the decrease was more noticeable. The mean MI value given in the text of that paper was 4.46 ± ± 1.12 mm; minimum: 1.2 mm; maximum: 8.55 mm, but according to the enclosed figures it shows a mean MI value that was only 2.5 mm.

MI or IC values described in numerous papers do not differ greatly. For example, in 9 female patients with radiographically evident fractures of thoracic vertebrae examined by Taguchi et al. [18] mean MI was 3.7 ± 0.9 mm, in comparison with a control group of 55 women with no signs of fractures in whom it was 3.9 ± 1.4 mm, and these values were not significantly different. In another study conducted by the same team of researchers MI ranges were similar in postmenopausal women after hysterectomy, postmenopausal women after oophorectomy or taking estrogen, as well as in women not affected by any of these conditions [16]. MI values were in the range 4 ± 1.0 mm in them. In a study by Yaşar and Akgünlü [20] in 27 osteoporotic females mean MI equalled 4.48 ± ± 1.24 mm, while in 21 non-osteoporotic women aged 40–64 years it was 5.04 ± 1.01 mm. In comparison, in our material mean MI in females aged 40–49 years equalled 3.48 ± 0.58 mm, and in the age group 50–59 years it was 3.34 ± 0.7 mm.

The only peer-reviewed paper of worldwide circulation discussing the practical applications of IC in Polish patients was published by Drozdzowska et al. [1] and presented data on 30 healthy postmenopausal women aged 48 to 71 years. Mean IC in the quoted study [1] was 4.71 ± 1.49 mm, while in the present study it was lower. However, it must be taken into account that our study group was more numerous and included a larger percentage of senile patients.

One of the frequently raised questions regarding MI or IC is regarding what threshold value should be used for detection of patients with low bone mass with the highest possible sensitivity and specificity [4, 9, 10]. It is crucial because the threshold of high sensitivity results in a larger number of healthy patients being referred for further examinations. On the contrary, higher specificity endangers sensitivity; therefore, some cases of osteoporosis will not be detected [9, 10]. In a study by Devlin and Horner [4] the MI threshold value characterised by moderate sensitivity and specificity was set at 4.34 mm. For threshold value of 3 mm specificity would be 100% for osteopaenia and 93.6% for osteoporosis, but sensitivity would be considerably compromised — 20% and 25.9%, respectively. In another study conducted by the same researchers [8], which was based on 126 female patients aged 45–55 years, the threshold value set at 3 mm. That resulted in detection of only 4 cases with decreased bone mass, which meant 99% specificity, but sensitivity of only 8%. Therefore, these authors concluded that MI was not sufficient in screening for osteopaenia and osteoporosis, even in combination with body mass index (BMI).

Nakamoto et al. [15] underlined that the combination of MI and qualitative evaluation of inferior mandibular cortex using MCI classification increases specificity of detection of individuals with low bone mass. On the other hand, the OSTEODENT Project conducted in several European countries focused on 671 women aged 45 to 70 years and concluded that the evaluation of IC width or MI index is highly effective in screening for osteoporosis, and the combination of these measurements with qualitative evaluation by means of MCI does not enhance diagnostic effects. According to researchers involved in the OSTEODENT Project, all individuals in whom IC is lower than 3 mm should be referred for further diagnostic tests for detection of osteoporosis [5]. In another paper based on 100 postmenopausal Japanese females the threshold was set at 4 mm when correlation with lumbar bone mineral density (BMD) was determined and 3.9 mm when femoral BMD was used [14].

A potential weakness of many studies on IC as a prognostic osteoporosis index is the relatively small number of examined subjects [1, 2, 16, 18]. The present study was based on as many as 877 subjects, and the group was even more extensive than in the OSTEODENT project (671 females).

CONCLUSIONS

1. It was found that IC and MI values in the studied group of Polish patients depended on age.
2. As far as gender is considered, IC and MI were higher in males.
3. When age and gender were discussed simultaneously, the highest values of IC and MI were observed in the age group 30–39 years in both genders, followed by a gradual decrease with age, but this decrease was more pronounced in females.
4. The elaborated norms of panoramic radiomorphometric parameters in Polish patients may serve as a source of comparison for radiological and clinical applications.

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