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Comparison of Radiomorphometric Index Measurements in the Mandible of Completely Edentulous Elderly and Middle-Aged Individuals**

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ABSTRACT:
Purpose: The present retrospective research aims to investigate the effect of sex and age on radiomorphometric indices that enable the evaluation of changes in the mandible in elderly and middle-aged edentulous individuals.
Materials-Methods: One hundred twenty-eight edentulous individuals (64 females, 64 males) aged 45-54, 55-64, 65-74, and 75-84 years were divided into four age groups. The mental index (MI), panoramic mandibular index (PMI), mandibular cortical index (MCI), and alveolar ridge resorption degree in the premolar regions (M/M ratio) of these individuals were assessed with regard to age and sex on panoramic radiographs.
Results: A significant increase was detected in the MCI class with increasing age ($p<0.05$). The MI, PMI, and M/M ratio were not affected by age ($p>0.05$). MI and PMI values in middle-aged and elderly individuals were affected by sex, and these values were found to be lower in females ($p<0.05$). No significant relationship was revealed between the M/M ratio and sex ($p>0.05$). It was observed that the MCI class was lower in females in the 45-54 age group ($p<0.05$).
Conclusion: Statistically significant relationships were defined in radiomorphometric index measurements (MI, PMI, M/M ratio, MCI) in elderly and middle-aged edentulous individuals depending on age and sex. The MI and PMI are affected by sex, and MCI by age. As age progresses, the mandibular cortex structure in females becomes more erosive. Changes in mandibular cortex morphology on panoramic radiographs of elderly individuals may be the effect of increased MCI class osteoporosis.
Keywords: *elderly individuals, mandibular cortical index, mental index, panoramic mandibular index, radiomorphometric index*

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INTRODUCTION

The mandibular cortex and alveolar process are consistently reshaped with age (Dutra et al., 2005), and the height of the alveolar ridge and basal bone decreases over time (Devlin and Horner, 2007; Heersche, Bellows, Ishida, 1998; Bianchi and Sanfilippo, 2002). It has been reported that there is a decrease in the density of the trabecular bone with aging, and this decrease in mineral density occurs due to loss of trabeculation and thinning of the trabeculae (Greenwood et al., 2018).

The mandibular cortex, which remodels with age, can also be affected by dentation and sex (Dutra et al., 2005). Bone loss takes place more quickly in the molar and premolar regions of the edentulous mandible than in the anterior region. Thus, the bone resorption of the basal bone is more commonly observed in the said region (Mercier, 1988).

Among dental radiographs, particularly panoramic images have been utilized with the aim of predicting low bone mineral density in subjects. Several radiomorphometric indices, such as the mandibular

cortical index (MCI), mental index (MI), and panoramic mandibular index (PMI), have been developed to identify osteopenia in the mandible on panoramic radiographs, observe the signs of resorption, and assess the quality of the mandibular bone mass (Devlin and Horner, 2002; Dutra et al., 2005; Devlin et al., 2007; Yüzügüllü, Gulsahi, Imirzalioglu, 2009).

Studies suggest that radiomorphometric indices can be used to screen patients who may potentially suffer from osteoporosis. Since most elderly individuals have the opportunity to go to a dental clinic rather than going to a medical clinic for the diagnosis of osteoporosis, it is essential to reveal the correlation between panoramic radiomorphometric indices and skeletal bone mineral density (Gulsahi et al., 2009).

Furthermore, there may be problems in the retention and stability of the prosthesis to be made as a result of losses in the cortical and trabecular bone in edentulous and elderly patients. A successful removable prosthesis requires a particular amount of underlying bone for stability in the course of chewing (Papamanthos et al., 2014). There is also a direct association between the success rate of a number of dental procedures such as dental implants and jawbone quality (Bodade and Mody, 2013).

In the current research, morphological changes in the cortical and trabecular structures of the mandible on digital panoramic radiographs were examined with radiomorphometric indices because their calculations are relatively easy.

MATERIALS AND METHODS

Purpose and Type of the Study

The research aimed to investigate the effects of sex and age on radiomorphometric indices (PMI, MI, MCI) and the alveolar ridge resorption degree in the premolar regions (M/M ratio) in an elderly and middle-aged edentulous population. This was a research study.

Sampling and Participant

Digital panoramic radiographs of completely edentulous patients in the 45-84 age range who presented to the Oral and Maxillofacial Radiology clinic between 2018-2021 were scanned.

With regard to the individuals included in the study, individuals without a history of systemic disease and trauma and without drug use were selected in accordance with the anamnesis data recorded in the system. Furthermore, individuals were excluded from the research when the image quality did not allow for a healthy examination due to reasons such as the presence of pathology, e.g., cyst/tumor in the maxillofacial region, a history of previous or current orthodontic treatment, artifacts in panoramic images, positioning errors, inability to observe the mental foramen, bifid mental foramen status, etc. Eighteen of 146 panoramic radiographs examined by a dentomaxillofacial radiologist were excluded from the study due to the inability to detect the mental foramen and positioning errors.

The sex and age of each patient, who were found to be completely edentulous, were recorded, and the patients' radiographs were divided into four age groups with 10-year intervals as 45-54, 55-64, 65-74, and 75-84 years. One hundred twenty-eight radiographs, involving 16 females and 16 males in each group, were enrolled in the research.

When a total of 32 male and female individuals were included in each age group with α=0.05, β=0.20, 1-β=0.80 and effect size (f)= 0.30, the power of the test was found to be 0.81.

Data Collection Tools

In this retrospective study, the same x-ray technician took panoramic radiographs with a panoramic x-ray machine in the P1 mode (Instrumentarium OP200 D, Instrumentarium Dental, Finland) in which automatic exposure factors (Ma, kVp) were adjusted by the device according to patient size. The criteria specified by the manufacturer of the device were followed while positioning patients. Accordingly, during the positioning of patients, attention was paid to ensure that the vertical line of the device was in the facial midline of patients and that the Frankfurt plane of patients was parallel to the floor.

The ImageJ 1.52b image analysis program downloaded from the internet address 'https://imagej.nih.gov'' was used for radiomorphometric measurements of individuals in 4 groups determined as completely edentulous.

Panoramic images in the JPEG format with 2976x 1536 pixels, 96 dpi, 8-bit resolution were included in this program and evaluated in a semi-dark and quiet environment. The measurements were performed by a dentomaxillofacial radiologist with 11 years of clinical experience, including 5 years of experience in maxillofacial radiology.

Evaluation and measurements are explained below (Hastar, Yilmaz, Orhan, 2011):

Mandibular Cortical Index (MCI): It was described by Klemetti, Kolmakov, Kröger in 1994. In this index, the mandibular cortex distal to the mental foramen is classified as three groups in accordance with its radiographic appearance (Klemetti, Kolmakov, Kröger, 1994):

C1: The endosteal margin of the cortex is flat on both sides.

C2: There are unilateral or bilateral resorption spaces and stratification (1-3 layers) at the endosteal border.

C3: The endosteal margin is clearly porous (Figure 1).

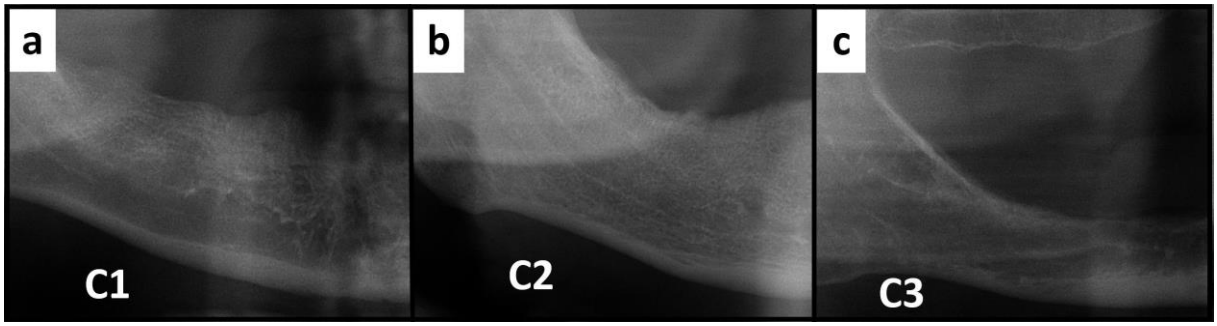

Figure 1. Examples of the mandibular cortex type. a) Mandibular cortical index C1, b) Mandibular cortical index C2, c) Mandibular cortical index C3

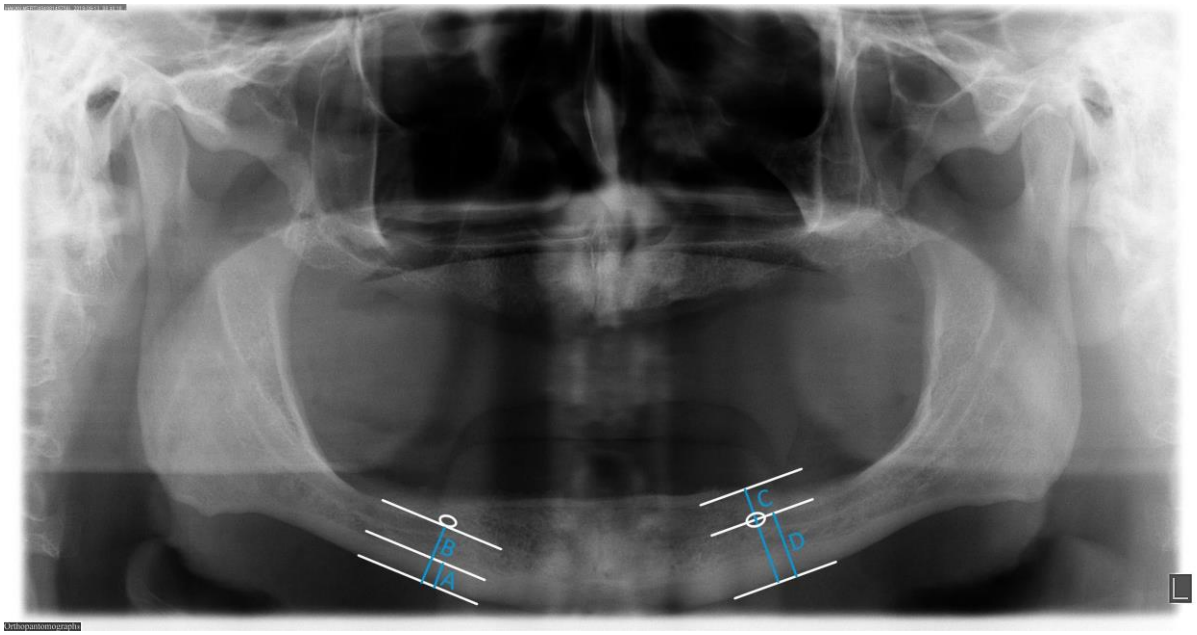

Figure 2. Mental index (A), panoramic mandibular index (A/B ratio), M/M ratio (C/D)

Mental Index (MI): It represents the thickness of the mandibular cortical bone in the mental foramen region defined by Ledgerton et al. (1997). The cortical thickness at the point where the line that passes through the midpoint of the mental foramen perpendicularly intersects the line running parallel to the long axis of the mandible and tangent to its lower border is measured (Ledgerton et al., 1997).

Panoramic Mandibular Index (PMI): The PMI is the ratio of the mandibular cortical thickness (MI) to the distance between the lower border of the mental foramen and the lower edge of the mandible (Benson, Prihoda, Glass, 1991).

Alveolar Ridge Resorption Degree (M/M ratio): It refers to the ratio of the total mandibular height, which represents mandibular alveolar bone loss, to the distance from the center of the mental foramen to the mandibular lower border (Dutra et al., 2006) (Figure 2).

The measurements were made on the right and left sides, and the morphology of the mandibular cortical bone distal to the mental foramen was evaluated on both sides. Two weeks later, 32 randomly selected radiographs (25%) were evaluated again by the same observer, intra-observer agreement was evaluated by a research assistant, and inter-observer agreement was investigated.

Statistical Analysis

The data acquired from the present research were loaded into the SPSS (22.0) program. Intraclass correlation coefficients (ICC), kappa statistics, and Kendall's tau test were used for intra-observer and inter-observer agreement.

In the data evaluation, the Kolmogorov-Smirnov test was used when parametric test assumptions were met, one-way analysis of variance (ANOVA) was conducted while comparing the measurements in more than two independent groups, and the chi-squared test was performed to evaluate the data obtained by counting. Number and percentage are given for the values obtained by categorical counting. The data are summarized as mean, standard deviation, and median in tabular form, and the error level was determined as 0.05. A p-value below 0.05 was accepted as statistically significant.

Ethical Approval

In the current research, which was carried out in accordance with the principles of the Declaration of Helsinki, approval was acquired from the Non-Interventional Clinical Research Ethics Committee of Sivas Cumhuriyet University (Decision No: 2022-01/13).

RESULTS

In the current research, the mean age of 128 completely edentulous individuals (64 females, 64 males) divided into 4 age groups was 64.05 ± 11.08. By keeping the male-female ratio equal in the groups, age groups and sexes were compared in terms of the MI, PMI, M/M ratio, and MCI.

There was no significant difference between the age groups with regard to the right and left MI, PMI, and M/M ratio values ($p>0.05$) (Table 1).

When the measurements of all individuals were compared according to sex, without considering the age groups, the right and left MI and right PMI values were found to be significantly lower in female individuals than male individuals ($p<0.05$) (Table 2).

When the age groups were analyzed in detail, the right MI values in the 45-54 age group and the right and left MI values in the 65-74 and 75-84 age groups were detected to be significantly lower in females ($p<0.05$). In the 75-84 age group, the right/left PMI values were found to be significantly lower in female individuals than male individuals ($p<0.05$). No relationship was found between sex and the M/M ratio in the age groups ($p>0.05$).

Upon comparing the right and left measurements, the right MI and right PMI values were revealed to be significantly higher compared to the left side in individuals in the 45-54 age group ($p<0.05$). The differences in other age groups were insignificant.

The MCI class increased with increasing age, and while C3 class was observed significantly more frequently in the 75-84 age group, C2 class and C1 class were observed significantly more frequently in the 65-74 and 45-54 age groups, respectively ($p<0.05$) (Table 3).

Table 1. Comparison of the Right and Left MI, PMI, and M/M Ratio Between the Age Groups

	Age Group	N	Mean±SD	Results
Right MI	45-54 years	32	56.17±8.79	F=1.28 P=0.282
	55-64 years	32	55.21±10.07	
	65-74 years	32	52.47±10.79	
	75-84 years	32	51.33±14.78	
Right PMI	45-54 years	32	0.37±0.06	F=0.89 P=0.444
	55-64 years	32	0.37±0.06	
	65-74 years	32	0.34±0.07	
	75-84 years	32	0.35±0.11	
Right M/M	45-54 years	32	1.83±0.32	F=0.78 P=0.504
	55-64 years	32	1.77±0.32	
	65-74 years	32	1.73±0.31	
	75-84 years	32	1.72±0.28	
Left MI	45-54 years	32	53.39±9.22	F=0.28 P=0.836
	55-64 years	32	54.25±12.31	
	65-74 years	32	51.84±11.08	
	75-84 years	32	51.98±15.59	
Left PMI	45-54 years	32	0.35±0.067	F=0.11 P=0.954
	55-64 years	32	0.36±0.078	
	65-74 years	32	0.35±0.087	
	75-84 years	32	0.35±0.10	
Left M/M	45-54 years	32	1.78±0.27	F=0.30 P=0.824
	55-64 years	32	1.72±0.29	
	65-74 years	32	1.72±0.32	
	75-84 years	32	1.72±0.31	

One-way ANOVA Test (p <0.05 denotes significance)

Table 2. Relationship Between Sex and the Right/Left MI, PMI, and M/M Ratio

	Sex	N	Mean±SD	Results
Right MI	Male	64	59.33±8.63	t=6.29 **P=0.001***
	Female	64	48.26±11.12	
Right PMI	Male	64	0.38±0.65	t=2.72 **P=0.007***
	Female	64	0.34±0.89	
Right M/M	Male	64	1.78±0.29	t=0.56 P=0.572
	Female	64	1.74±0.32	
Left MI	Male	64	57.78±10.60	t=4.98 **P=0.001***
	Female	64	47.95±11.70	
Left PMI	Male	64	0.36±0.075	t=1.68 P=0.094
	Female	64	0.337±0.091	
Left M/M	Male	64	1.75±0.30	t=0.40 P=0.684
	Female	64	1.72±0.29	

*Independent sample t-test, * p <0.05 denotes significance*

Table 3. Distribution of MCI in the Age Groups

		MCI				
		C1	C2	C3	Total	Result
Age groups	**45-54 years**	17(53.1%)	14 (43.8%)	1 (3.1%)	32 (100.0%)	X^2=29.87 p=0.001
	55-64 years	9 (28.1%)	19 (59.4%)	4 (12.5%)	32 (100.0%)	
	65-74 years	5 (15.6%)	21 (65.6%)	6 (18.8%)	32 (100.0%)	
	75-84 years	2 (6.3%)	17 (53.1%)	13 (40.6%)	32 (100.0%)	
Total		33 (25.8%)	71 (55.5%)	24 (18.8%)	128 (100.0%)	

*Chi-squared test; * p <0.05 denotes significance*

With age, the negative correlation observed in the right and left MI, PMI, and M/M values was statistically insignificant (p>0.05). However, the positive correlation observed in the MCI class was found to be significant (p<0.05).

When the correlation between the MCI and sex was examined, C1 class and C2 class were observed significantly more frequently in females and males, respectively, in the 45-54 age group (p<0.05). No significant difference was revealed between sexes in terms of MCI in other age groups (p>0.05) (Table 4).

It was found that intra-observer and inter-observer agreement ranged from high to perfect in 32 randomly selected radiographs (Table 5).

Table 4. Relationship Between Sex and MCI in the Age Groups

Age group	Sex	MCI			Result
		C1	C2	C3	
45-54 years	Male	5 (31.3%)	11 (68.8%)	0	**X^2=8.45**
	Female	12(75.0%)	3 (18.8%)	1 (6.3%)	**P=0.015***
55-64 years	Male	5 (31.3%)	10 (62.5%)	1 (6.3%)	X^2=1.16
	Female	4(25.0%)	9(56.3%)	3(18.8%)	P=0.559
65-74 years	Male	3(18.8%)	11(68.8%)	2(12.5%)	X^2=0.91
	Female	2(12.5%)	10(62.5%)	4(25.0%)	P=0.633
75-84 years	Male	1(6.3%)	10(62.5%)	5(31.3%)	X^2=1.22
	Female	1(6.3%)	7(43.8%)	8(50.0%)	P=0.543

*Chi-squared test; * p <0.05 denotes significance*

Table 5. Statistical Analysis Results Showing Intra-Observer and Inter-Observer Agreement for 32 Randomly Selected Radiographs

	Intra-Observer Correlation Coefficient (ICC)	Inter-observer Correlation Coefficient (ICC)***	p-value
MCI **	0.837	0.924	0.001**
Right MI	0.999	0.970	0.001*
Left MI	0.999	0.982	0.001*
Right PMI	0.999	0.975	0.001*
Left PMI	0.999	0.981	0.001*
Right M/M ratio	0.999	0.983	0.001*
Left M/M ratio	0.999	0.999	0.001*

** p <0.05 denotes significance. ICC: Intra-class correlation coefficient*

*** Kappa statistics were conducted for MCI values.*

**** Kendall's tau test was used for inter-observer agreement.*

DISCUSSION

Constant reconstruction can be observed in the mandibular cortex depending on age, sex, oral health, and dentition status (Bathla et al., 2018), and the quality of the mandibular bone may be affected by these conditions (Dutra et al., 2005).

After the teeth are extracted, the jaws constantly undergo alveolar ridge atrophy. This process takes place more severely in the mandible compared to the maxilla (Von Wowern, 1986). In the literature, some studies evaluated the interaction of dentition with radiomorphometric index values in adults (Dutra et al., 2005; Hastar, Yılmaz, Orhan , 2011; Ledgerton et al., 1999; Okabe et al., 2008; Yüzügüllü, Gulsahi, Imırzalioglu, 2009).

In their study conducted on 487 elderly individuals aged between 60-88 years, Hastar, Yılmaz and Orhan (2011) divided the study group into completely dentulous, partially dentulous, and completely edentulous patients and determined that the mean MI and PMI values of edentulous subjects were lower. While Ledgerton et al. (1999) showed that the MI values were lower in partially or completely edentulous individuals, Moradi et al. (2017) reported that the M/M ratio decreased in subjects with more missing teeth (p<0.05). In all three studies above,

higher MCI classes were found in edentulous patients (p<0.05). There are also studies reporting that tooth loss has no effect on MI and PMI (Dutra et al., 2005; Moradi et al., 2017; Mostafa, El-Ashiry, Farid, 2011).

Although the age range was kept wide in many studies above, the number of teeth of individuals also varied. The reason for these different results in studies may be due to age and race diversity. Furthermore, in subjects with a long history of edentulism, masticatory forces may decrease, and the mandibular cortex may be affected as a result of insufficient occlusal forces (Hastar, Yilmaz and Orhan, 2011). This study was conducted only on completely edentulous elderly individuals so that radiomorphometric index values would not be affected by the dental condition.

Various studies have reported a decrease in MI and PMI values in males and females depending on age (Benson, Prihoda, Glass, 1991; Dutra et al., 2005; Mostafa, El-Ashiry, Farid, 2011).

Mostafa, El-Ashiry, Farid (2011) reported that the MI and PMI were highly affected by age, and a significant decrease was observed in MI values after the 4th decade and in PMI values after the 6th decade. In their study, Ledgerton et al. (1999) reported a negative correlation between MI and age and indicated that MI decreased with the increasing age. Moradi et al. (2017) found a significant decrease in the MI and M/M ratio with age in the study group aged 20-86 years and reported that PMI was not influenced by age. In the research conducted by Yüzügüllü, Gulsahi, Imirzalioglu (2009) on 94 edentulous individuals categorized as over 60 and under 60 years of age, the MI and PMI and the mean bone heights measured from the mandibular 1st molar and 1st premolar tooth regions were not affected by age.

The absence of a significant difference between the MI and age groups in the present research can be explained by the fact that the age groups were close to each other. Due to the inclusion of dentulous individuals in other studies, parafunctional conditions are likely to affect the results. The bone may have been protected from excessive resorption as a result of muscle hyperactivity due to the presence of parafunctional conditions in the posterior mandible (Bianchi A, Sanfilippo, 2002).

Middle-aged and elderly individuals may be influenced by osteoporosis, which has been stated to reduce MI and PMI values, and this can indicate bone mineral changes (Gulsahi, 2015; Martínez-Maestre et al., 2013). The measurement of the mandibular cortical width on panoramic radiographs has been proposed to predict subjects with low bone mineral density (Dutra et al., 2005). Previous research has demonstrated significant correlations between MI and bone mineral density (Devlin, Horner, 2002; Devlin, Horner, 2007; Horner, Devlin, 1998; Klemetti et al., 1993; Okabe et al., 2008).

The MI, which was calculated to be lower in the 65-74 and 75-84 age groups, although not significantly, in this study, can suggest that bone mineral density is lower in these age groups and these patients may be more prone to osteoporosis. It is possible to diagnose osteoporosis by panoramic radiography in dental clinics (Nemati et al., 2016), and subjects with thin mandibular cortex may be referred for further examination such as DXA due to the high risk of osteoporosis.

In their study, Dölekoğlu et al. (2015) researched the effects of disorders influencing the skeletal metabolism in completely edentulous subjects, compared the PMI values on the right or left side of the mandible, and found no difference between them.

In the current research, the right MI and right PMI values were revealed to be significantly higher compared to the left side only in individuals in the 45-54 age group (p<0.05). This may be due to the fact that the cortex structure was affected by unilateral masticatory habits in the 45-54 age group, which is considered to have the shortest period of edentulism among age groups.

Many studies have mentioned changes in the mandibular cortical bone morphology with age (Moradi et al., 2017; Gulsahi et al., 2008). Gulsahi et al. (2008) reported that the incidence of C3 increased with age, and in the logistic regression analysis, the probability of incidence of C3 increased by 9.17 and 79.14 times in the 50-69 age group and the group over 70 years of age, respectively, compared to the 20-49 age group. In the research conducted by Moradi et al. (2017), no significant correlation was

found between the MCI and age. However, it was demonstrated that the chance of having C2 and C3 classes of MCI increased with the decrease in MI and was reported that the PMI and M/M ratio also decreased with the increase in MCI class ($p<0.05$).

In the current research, C3 class was detected more frequently in the 75-84 age group, C1 class was found more frequently in the 45-54 age group, and a significant increase was revealed in MCI classes with the increasing age ($p<0.05$). These results show that bone quality decreases with age, and we think that prosthetic treatments (e.g., full removable prosthesis and implant) to be performed as age progresses may be affected by this situation.

Contrary to some studies in the literature reporting more advanced bone loss in females compared to males (Hastar, Yilmaz, Orhan, 2011; Mostafa, El-Ashiry, Farid, 2011), there are also studies reporting different results (Gulsahi et al., 2008; Moradi et al., 2017; Yüzügüllü, Gulsahi, Imirzalioglu 2009).

In the research carried out by Hastar, Yılmaz, Orhan (2011), mean MI and PMI values in female individuals over 60 years of age were significantly lower compared to male individuals in the same age group ($p<0.05$). It was reported that C1 class in male individuals and C2 class in female individuals were observed more frequently. However, C3 class was observed only in females. The reason for differences between sexes was associated with a higher incidence of osteoporosis in females. Furthermore, these results may have been affected by the dental condition.

In their study on 270 panoramic radiographs in the 20-86 age range, Moradi et al. (2017) did not reveal a significant correlation between MI and sex. However, the M/M ratio and PMI were higher in female individuals compared to male individuals. In terms of MCI, C2 and C1 were observed more frequently in males and females, respectively. These results may have been affected by the lower mean age of females compared to males in the study. Furthermore, the fact that different findings were obtained than the study by Hastar, Yilmaz, Orhan (2011) may also be associated with the lower mean age in the present study.

Yüzügüllü, Gulsahi, Imirzalioglu (2009) did not determine a significant difference between sex and MI, PMI, alveolar bone loss, and mean bone heights. However, a significant interaction was found between age and sex. There was no change in the mean MI values with the increasing age in males, but they decreased significantly with age in females ($p<0.05$). C3 class was found in 75% of females over 60 years of age, and no relationship was found between sex and MCI between age groups in males.

In the study by Mostafa, El-Ashiry, Farid (2011), the mean MI values were significantly lower in female individuals than in male individuals, and the PMI was not influenced by sex.

In the current research, when all individuals were examined without considering the age groups, the MI and right PMI values were affected by sex and were found to be lower in females ($p<0.05$). The difference between sex and M/M ratio was insignificant ($p>0.05$). Muscle strength, hormonal and metabolic differences due to sex differences may have affected these results. Furthermore, the fact that C1 class was observed significantly more frequently in females in the 45-54 age group compared to males suggests that males in this age range tend to have more erosive cortex compared to females. However, in this retrospective study, the inability to fully evaluate systemic disease and osteoporosis, the inability to evaluate parafunctional habits, and the lack of knowledge about the time since the extraction of the tooth and teeth are the limitations of our study and may affect the results (Devlin, Ferguson, 1991).

CONCLUSION

In the present study conducted on completely edentulous elderly and middle-aged individuals, statistically significant relationships were identified in radiomorphometric index measurements (MI, PMI, M/M ratio, and MCI) depending on age and sex. The MI and PMI are affected by sex, while the MCI is affected by age. Changes in the mandibular cortex morphology as a result of decreased bone density in panoramic radiographs of elderly individuals may be the effect of increased MCI class osteoporosis. These radiographs can be used for primary screening prior to DXA examination in the evaluation of osteoporosis. Further studies that exclude systemic diseases, masticatory and parafunctional habits are

needed for more reliable results.

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Conflict of Interest

None declared.

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