E-ISSN: 2792-0739

JOURNAL OF SOCIAL AND ANALYTICAL HEALTH

www.jsoah.com

J Soc Anal Health, 2023, 3(1): 18-25

Research Article / Araştırma

Comparison of mandibular radiomorphometric indices on digital panoramic radiography and cone-beam computed tomography images in terms of osteoporosis risk detection

Mandibular radyomorfometrik indekslerin dijital panoramik radyografi ve konik ışınlı bilgisayarlı tomografi görüntülerinde osteoporoz risk değerlendirmesi bakımından karşılaştırılması

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ABSTRACT

Aim: The aim of this study was to compare the assessment of mental index, mandibular cortical index and bone quality index on digital panoramic radiography and cone-beam computed tomography. **Materials and Methods:** Digital-panoramic-radiography and cone-beam-computerized-tomography images of 113 dental-patients who aged more than 45 years without systemic diseases were evaluated. The patients were divided into two groups according to mental-index (which was measured on panoramic-radiography) value set by ?3 mm; the patients with osteoporosis risk and without. Mental-index was performed on both side(left-right), and the average value of two measurements was calculated. Mental-index, computerized-tomography-mental-index, mandibular-cortical-index, computerized-tomography-cortical-index and bone-quality-index were measured on digital-panoramic-radiography and cone-beam-computerized-tomography by two observers. Descriptive and logistic regression statistics were performed; $p<0.05$ was considered significant. **Results**: The results of both methods were consistent with each other. For observers there were statistically significant differences between the osteoporotic risk-groups and the normal-groups for computerized-tomography-mental-index ($p<0.001$), mandibular-cortical-index/computerized-tomography-cortical-index, bone-quality-index. According to first and second observers' measurements the optimum threshold value of computerized-tomography-mental-index was found respectively 3.01mm and 3.03mm for the risk of osteoporosis. The correlation(weighted-kappa-test) between mandibular-cortical-index and computerized-tomography-cortical-index values for observers' evaluations respectively (1st and 2nd observer) was moderate and high. The frequency distributions of 1,2,3 classes were found significantly different($p<0.05$) in both individuals with(osteoporotic) and without(healthy) risk of osteoporosis for bone-quality-index values in both digital-panoramic-radiography and cone-beam-computerized-tomography images. **Conclusions**: cone-beam-computerized-tomography images can be used to assess the osteoporosis. By determining a threshold value in cone-beam-computerized-tomography, awareness of the patient can be raised by the dentist according to the status of these values, which can be easily measured on the image.

ÖZ

Amaç: Bu çalışmanın amacı, dijital panoramik radyografi ve konik ışınlı bilgisayarlı tomografi üzerindeki mental indeks, mandibular kortikal indeks ve kemik kalite indeksinin değerlendirilmesini karşılaştırmaktı. **Gereç ve Yöntem:** Herhangibir sistemik hastalığı olmayan 45 yaşüstü 113 hastanın panoramik-radyografi ve konik-ışınlı-bilgisayarlı-tomografi görüntüleri değerlendirildi. Mental indeks (panoramik radyografi üzerinde ölçüldü.) değeri '≤ 3 mm' değerine göre hastalar osteoporoz riski olan ve olmayan şeklinde iki gruba ayrıldı. Mental-indeks her iki tarafta da (sol-sağ) ölçüldü ve iki ölçümün ortalaması hesaplandı. Mental-indeks, bilgisayarlı tomografi mental indeksi, mandibular kortikal indeks, bilgisayarlı tomografi kortikal indeks ve kemik kalite indeksi, panoramik-radyografi ve konik-ışınlı-bilgisayarlı-tomografide iki gözlemci tarafından ölçüldü. Tanımlayıcı ve lojistik regresyon istatistikleri yapıldı; $p < 0.05$ anlamlı kabul edildi. **Bulgular**: Her iki yöntemin (panoramik-radyografi, konik-ışınlı-bilgisayarlı-tomografi) sonuçları birbiriyle uyumluydu. Gözlemciler için osteoporoz risk grupları ile normal gruplar arasında bilgisayarlı-tomografi-mental-indeksi ($p<0.001$), mandibular kortikal indeks-bilgisayarlı tomografi kortikal indeks, kemik kalite indeksi için istatistiksel olarak anlamlı farklılıklar bulundu. Birinci ve ikinci gözlemcinin ölçümlerine göre osteoporoz riskini değerlendirmek için bilgisayarlı-tomografi-mental-indeksin optimum eşik değeri sırasıyla 3.01 mm ve 3.03 mm bulundu. Gözlemci değerlendirmelerinde mandibular kortikal indeks ve bilgisayarlı tomografi kortikal indeks değerleri arasındaki korelasyon (ağırlıklı kappa testi) sırasıyla (1. ve 2. gözlemci için) orta ve yüksek çıktı. Hem panoramik-radyografi hem de konik-ışınlı-bilgisayarlı-tomografi görüntülerinde kemik kalite indeks değerleri için 1,2,3 sınıfının sıklık dağılımları osteoporoz riski olan ve olmayan bireylerde anlamlı olarak farklı bulundu ($p<0.05$). **Sonuç**: Konik-ışınlı-bilgisayarlı-tomografi görüntüleri osteoporozu değerlendirmek için kullanılabilir. Tomografide bir eşik değer belirlenerek, hastanın radyografik görüntüsü üzerinde kolayca ölçülecek bu değerlerin durumuna göre diş hekimi tarafından farkındalık uyandırılabilir.

ARTICLE INFO/MAKALE BİLGİSİ

Key Words: Cone Beam Computerized Tomography, Osteoporosis, Panoramic Radiography

Anahtar Kelimeler: Konik Işınlı Bilgisayarlı Tomografi, Osteoporoz, Panoramik Radyografi

DOI: 10.5281/zenodo.7528103

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Received Date/Gönderme Tarihi: 01.12.2022

Accepted Date/Kabul Tarihi: 12.01.2023

Published Online/Yayımlanma Tarihi: 17.03.2023

INTRODUCTION

Osteoporosis is a disease with high morbidity and mortality that affects the quality of life of human, especially menopausal women. It affects more than 75 million women in Europe, Japan and USA According to the estimates of the European Union, it is thought that the number of people affected by this disease will increase from 414.000 to 972.000 annually in the next 50 years (1,2). Preventive measures and early detection are believed to significantly reduce these rates.

Osteoporosis provokes bones to become weak and fragile — so fragile that a minor fall or even minor trauma can cause a fracture. Fractures due to osteoporosis generally occur in the hip, wrist or spine.

In previous studies, it was determined that the decrease in bone mineral density (BMD) in osteoporotic patients affects the mandible morphometrically, densitometrically and structurally (3). There are studies showing that thinning of the mandibular cortical bone in menopausal women can usually be observed on panoramic radiographs (4). This cortical thinning in the mandible occurs with the enlargement of Havers canals (5). Mental index (MI) and Computerized Tomography Mental Index (CTMI) are important indices that evaluate bone quality based on this cortical structure.

It is characterized by constant loss of bone and one of the most common bone diseases. It is thought that the first sign of general bone loss, which is a characteristic finding of osteoporosis, may be alveolar bone loss. The relationship between osteoporosis and oral bone loss put forward firstly in 1960's (6). This is followed by vertebra and long bone losses. Epidemiological studies have shown that bone loss in the lower jaw is consistent with overall bone loss in the body in patients with osteoporosis (6-8). Patients with osteoporosis have slightly decreased trabeculae in spongious bones while cortex and lamina dura are thinner than healthy patients (9,10).

Although this disease does not have a significant symptom in the early stages, but on the progressing stage it may cause fractures even because of minor traumas. It has high mortality and morbidity rates, and its diagnosis and treatment are expensive (7,8). So, the early diagnosis is extremely important in osteoporosis such as the other diseases (11).

The aim of this study was to emphasize both the active role of dentists at the early diagnosis of osteoporosis and the effectivity of some radiomorphometric indices such as MI, mandibular cortical index (MCI) and bone quality index (BQI) in determining the risk of osteoporosis. Although these indices are not effective for definitive diagnosis of osteoporosis, they can build the basis of diagnosis by determining the risk of disease.

The current study's hypothesis is the patients that have low values of radiomorphometric indices on Digital-Panoramic-Radiography, will have low values of the same indices on Cone-Beam-Computerized-Tomography (CBCT). The second hypothesis is that there is a threshold value for MI value on CBCT.

MATERIALS AND METHODS

This study was approved by the Gülhane Military Medical Academy Ethics Committee (38/2014). Patients who applied to Ankara GATA Dental Sciences Center between 2011 and 2015 for their routine dental complaints were included to the study and the principles of the Declaration of Helsinki, including all amendments and revisions were followed during oral examination.

During the study, the images of patients underwent both DPR (Digital Panoramic Radiography) and CBCT (Cone-Beam Computerized Tomography) at most one month apart were evaluated. Images of patients over 45 years old were included in the study. Thus, the study group consisted of a total 113 patients; 64 women and 49 men, aged 45-81 (mean: 60.92+_7.46).

It was not taken into consideration whether the patients included in the study had osteoporosis or not. The patients excluded from the study who had a disease that affects the bone metabolism such as thyroid disease, hyperparathyroidism, diabetes, chronic renal disease, drug users and patients undergoing hormone replacement therapy. The images that form the study group were selected from among those radiographically who did not have any lesions (malignant tumor, osteomyelitis, etc.) that could cause bone destruction in the mandible. The images were excluded from the study which had cystic or tumoral lesion, had an operation through the mandible like resection and didn't have the adequate imaging field (in CBCT; inadequate FOV).

Radiographic measurements

All DPRs were taken by Kodak 8000C Digital Panoramic System (Eastman Kodak Company, Rochester, New York, US, 12 mA, 13.9 s, 73 kWp). Patients' head was fixed with the stabilizer in each position. The measurements were performed with using the device's own software program (Kodak Dental Imaging Software Viewer, version 6.12.10.0, Eastman Kodak Company, Rochester, New York, US.) on DPR. All the images were evaluated on the same monitor (HP Compaq LE1711 LCD Monitor, Palo Alto, CA, USA). The magnification coefficient of DPR device was found as 0.25. After the measurements were multiplied by this value, statistical analysis was performed.

CBCT scans (field of view (FOV): 170*120 mm) used in the study were obtained by 3D Accuitomo 170 system (J Morita Mfg. Corp., Kyoto, Japan). Acquired data were consisted of 12 bit-grey scale depth with a 0.25 mm3 isotropic voxel size. The measurements on CBCT were performed using the scale in the I-dixel program. All the patients' CBCT images were evaluated on the same monitor (1920x1200 pixel, 32 bit, DELL, TX, USA). CBCT image data were analyzed by using bone quality assessment methods which suitable for CBCT image analysis; radiomorphometric analysis.

MI was measured on the line which was perpendicular to the line that is the tangent to the bottom of the mandible at the middle of the foramen mentale on DPR (12).

CTMI is the inferior cortical width of the mandible on CBCT images as described by Ledgerton et al (Ledgerton et al); Cross-sectional images were taken with 1mm intervals on axial plane (13). The index was measured on the section in which the mandibular canal opens through the mouth, region where foramen mentale is clearly seen. MI and CTMI was detected bilaterally (right-left) and statistical analysis were made by taking the average of two values.

Lindh et al developed a BQI evaluating the trabecular bone based on Lekholm and Zarb's classification (14,15). According to this classification the types of bone were written below.

1. Homogeneous and dense

2. Heterogeneous.

3. Homogeneous and sparse. BQI were assessed on both of CBCT and DPR images in the study group.

For the evaluation of MCI distal of mental foramen is examined bilaterally. The classification of MCI was made by Klemetti (17). MCI was examined on DPR and also evaluated on CBCT as Computed Tomography Cortical Index (CTCI)

C1: The endosteal cortical margin is straight, uniform, and sharp on both sides.

C2: the endosteal margin has semi-lunar defects (lacunar resorption) or endosteal cortical residues on one or both sides, mild to moderate cortex erosion.

C3: the cortical layer forms heavy endosteal cortical residues and is clearly porous, severely eroded cortex.

All measurements were performed independently by two researchers at different times on the same computer. To control the repeatability and reliability of the measurements, 1 week later the researchers were repeated the measurements on 40 randomly selected radiographic images and compliance with the first measurements was checked.

Patients with a mental index of less than 3mm were considered to be at risk for osteoporosis.

Data analysis

Descriptive and logistic regression statistics were performed; $p < 0.05$ was considered significant. In this study data sets that were created by researchers with using the DPR and CBCT images of 113 patients analyzed. Descriptive statistical analysis, ROC analysis, Student T-test, Kappa test, Intra Class Correlation Coefficient, Pearson Correlation test were used. In this study a threshold value is used that is available for DPR; MI≤3mm for osteoporosis risk assessment and it is accepted as a standard.

RESULTS

Descriptive statistical analyzes, student t-test and ROC Curve were used to find a threshold value of CTMI on CBCT that corresponding to the threshold value of "MI≤3 mm" on DPR. With this study based on MI threshold, which is accepted as standard, a CTMI threshold value was researched. According to this standard threshold there was a significant difference in CTMI value between the individuals at risk of osteoporosis and not ($p<0.001$). According to the observer first's and observer second's measurements respectively the optimum threshold values of CTMI were found 3.01 mm and 3.03 mm (Figure-1; ROC curve analyses of CTMI value for Observer 1 and 2 (O1-O2)).

Results indicate significant difference between two groups for both observers (respectively) via 91.3%, 93.3 % (2) sensitivity and 88.2%, (1) specificity for both and there is about 1% deviation between DPR and CBCT in terms of threshold of osteoporosis risk, therefore the two techniques are consistent and compatible (1The ability of a test to distinguish between those who are really sick, 2The ability of a test to distinguish between those who are not really sick).

Compatibility was evaluated between the researchers. According to the threshold value (MI≤3mm) accepted as standard; among the researchers' high agreement was found to identify the individuals with and without the risk of osteoporosis (Kappa test, $p<0.001$). High agreement was found between the researchers at the measurement of MI and CTMI by Intra Class Correlation Coefficient Test.

In researchers' assessments for both MCI and CTCI; the evaluation of C1, C2, C3's distribution of frequency was found significantly different between the individuals with risk of osteoporosis(osteoporotic) and without(healthy) ($p<0.001$) (Table 1).

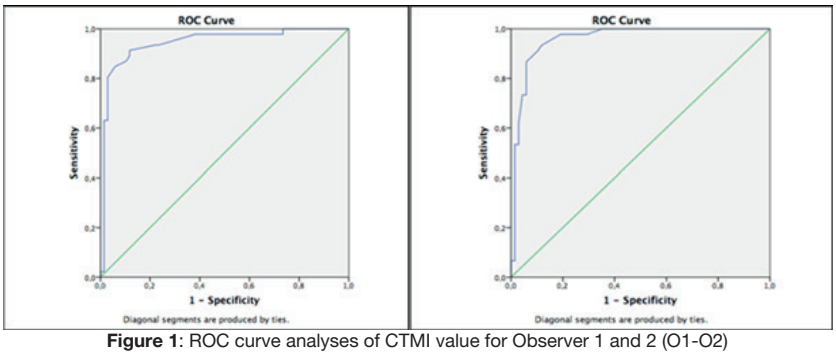

Figure 1: ROC curve analyses of CTMI value for Observer 1 and 2 (O1-O2)

Table.1 MCI and CTCI values were evaluated comparatively in risky and risk-free groups with chi-square test.

		MI Observer-1				
		Osteoporotic(Risky)		Healthy(Risk-free)		
		N	N%	N	N%	P*
MCI	C1	15	35	28	65	
	C2	31	66	15	34	<0.001
	C3	22	92	2	8	
CTCI	C1	5	18	23	82	
	C2	36	66	18	35	<0.001
	C3	27	87	4	13	

		MI Observer-2				
		Osteoporotic(Risky)		Healthy(Risk-free)		
		N	N%	N	N%	P*
MCI	C1	16	39	25	61	
	C2	28	64	16	36	<0.001
	C3	24	86	4	14	
CTCI	C1	15	39	24	62	
	C2	26	62	16	38	<0.001
	C3	27	84	5	16	

*chi-square

The correlation (weighted kappa test) between MCI and CTCI values for both observers' evaluations respectively was moderate (weighted kappa coefficient=0.669) and high (weighted kappa coefficient=0.84)

For the first time in this study, the risk of osteoporosis was evaluated by comparing the BQI in DPR and CBCT images. As a result of the statistics of the measurements, the frequency distributions of the 1, 2 and 3 classes in both the DPR and CBCT images of the individuals with and without the risk of osteoporosis were found to be significantly different ($p<0.05$) (Table 2).

The agreement of the evaluation results in the panoramic radiography and CBCT images of the BQI index was low for the first observer (Kappa coefficient = 0.48), and medium for the second observer (Kappa coefficient = 0.56). Considering that CBCT is much more reliable in evaluating the bone structure, according to all these results regarding the BQI index, the low agreement between them because of the study raises doubts about the reliability of the evaluation of the BQI index with panoramic radiography. A high agreement was found between the 2 observers in terms of all measurements (weighted kappa test).

Table.2 BQI values was detected in DPR and CBCT were evaluated in risky and risk-free groups cmpared with chi-square.

		O1				
		Osteoporotic(risky)		Healthy(risk-free)		
		N	N%	N	N%	P*
BQI_DPR	C1	12	33	24	67	
	C2	45	76	14	24	<0.001
	C3	11	61	7	39	
BQI_CBCT	C1	5	31	11	69	
	C2	40	60	26	40	0.018
	C3	23	74	8	26	

		O2				
		Osteoporotic(risky)		Healthy(risk-free)		
		N	N%	N	N%	P*
BQI_DPR	C1	9	32	19	68	
	C2	47	71	19	29	0.002
	C3	12	63	7	37	
BQI_CBCT	C1	4	27	11	73	
	C2	37	60	25	40	0.006
	C3	27	75	9	25	

* chi-square test

DISCUSSION

The hypothesis that radiomorphometric indices will be compatible in panoramic radiography and CBCT images has been corrected. As expected, the results were congruent. A threshold value was found for MI on CBCT(CBCT) as expected.

Devlin et al evaluated the mental indices measured on the patients' panoramic radiographs and evaluated the measurements according to the results of DEXA (17). They found MI threshold value for the risk assessment was '≤3mm'. Similarly in the study of Hastar et al, Gaur et al, the MI values differed significantly between being with and without osteoporosis (18,19). Based on this and many similar studies, the use of MI values in the evaluation of osteoporosis has become indisputable.

It is known that there is a correlation between a thin mandibular cortical width (MI) and decreased BMD. Horner et al concluded in their study that low skeletal bone mass is associated with MI≤3mm threshold value (20). In the study conducted by Devlin and Horner, they found that MI significantly contributed to the diagnosis of low skeletal BMD and the most appropriate diagnostic threshold value for MI is 3mm, and these patients should be directed to BMD measurement (21). Vlasiadis et al suggested that a 1mm decrease in MI value will increase the probability of osteopenia by 43%, and an increase in loss of 1 tooth will increase the probability of cortical erosion by 6% (22).

It can be concluded that the diagnosis of this risk with panoramic radiographs taken due to the dental complaints of patients with high osteoporosis risk is a highly effective strategy that confirms the DEXA measurement to avoid the medical consequences that may be caused by the complications of the disease and the unnecessary expenses caused by the treatment of these results. White et al analyzed the clinical and radiographic images and defined the MI as the most useful osteoporosis risk determination factor clinically (23). Mahl et al supported the same hypothesis and demonstrated that the MI value showed a significant difference between the osteoporotic, osteopenic and healthy study groups (24). Elkersh et al found significant positive correlation between CTMI and T-score measured by DEXA in their study on 24 postmenopausal women (25). Similarly, Brasileiro conducted a study that the CTMI value was lower in the osteoporotic female patient group compared to the osteopenic and normal female patient group (26). Therefore some threshold values should be determined for indices

used in osteoporosis risk assessment for CBCT as in panoramic radiographs. In this study, a significant difference was found in other measurements in terms of the MI threshold value determined by all these studies in panoramic radiography in terms of osteoporosis risk.

Seçgin et al in their assessment of cross-sectional and panoramic images obtained with CBCT in 182 patients; MI and CTMI values compatible with each other (27). However, what this cortical threshold value on CBCT is important, because this threshold affects the diagnosis in terms of both sensitivity and specifity.

In the light of all these studies, it was concluded that the ideal threshold value in terms of sensitivity and specificity for MI, which can be used in osteoporosis risk determination, is ≤3mm. In the present study, it was assumed that individuals with this threshold value and below have the risk of osteoporosis. The CTMI equivalent of this threshold value measured in CBCT axial plane oblique sections was investigated. According to the threshold value of '≤3mm' (MI) in panoramic radiography, a statistically significant difference was found in terms of CTMI value between individuals at risk of osteoporosis and those who do not ($p<0.001$). Accordingly, 3.01 and 3.03 mm were determined as the optimum threshold value (cut-off point) for CTMI in the measurements of the first and the second observer, respectively. These results from the study show that there is a deviation of approximately 1% in terms of osteoporosis risk threshold (cut-off point) between DPR and CBCT (MI and CTMI indices), so the two techniques are consistent and a good fit.

In many studies conducted in recent years, it has been concluded that the decrease in mandibular cortical thickness and the formation of porosity in the inferior cortical structure can be evaluated as an increase in osteoporosis risk. Mandibular inferior cortex structure is scored according to the criteria specified by Klemetti according to its appearance (19,28,29). Pal and Amrutesh claim that a single index measurement will not be sufficient in determining osteoporosis risk, MI and MCI values should be evaluated together (30).

One of the results that is obtained in this study confirms the theory of Pal and Amrutesh (30). Based on this study's results, it can be suggested that there is a strong correlation between MI and MCI and should be evaluated together. At this point, it is thought that evaluating mainly MI and MCI values together in risk determination will give more accurate results.

Bone density of individuals after about the 3rd decade of life while the decrease is observed, there is an increase in porous structure in these bones (23,31). Some changes in the mandibular structure, especially in the inferior cortex, together with decreased jaw bone mass in osteoporosis disease is seen (32).

Gülşahi et al found that patients with MI≤3mm were more likely to be in the C3 category according to the Clemetti classification than patients with MI>3mm (33). There are many studies proving that the risk of osteoporosis increases in the case of C3 according to the Klemetti classification (19,28,34,35,36).

Until today there are few studies which compare the panoramic radiographs and cone-beam computed tomography in terms of the indices using for the risk assesment of osteoporosis. However, due to its wide and increasing use in dentistry, it has become important to carry out these risk assessments on CBCT images. It will be very beneficial for the patient to be able to determine the risk of osteoporosis on a CBCT image taken for the dental reasons, as it gives more accurate information about bone quality and quantity.

When Gomes et al scored the MCI on the panoramic image obtained from the axial plane sections and the oblique sections obtained from the sagittal plane in the CBCT images, they found that the results were compatible with each other (37). While the interobserver agreement was higher in sagittal sections compared to panoramic views. In this study, the two techniques show a good consistent. In terms of inter-observer agreement, it was found that there is high agreement in all indices. In the measurement of the parameters evaluated on the CBCT images for both observers, intraobserver agreement was found to be high.

In the studies of Koh and Kim, while a significant difference was found between normal and osteoporotic individuals in terms of CTCI, no significant difference was found between the two groups in terms of CTMI on CBCT. Contrary to Koh and Kim, this study was found a significant difference for the two groups in terms of CTMI and CTCI in individuals with and without osteoporosis risk (38).

Castro et al found that postmenopausal woman with osteoporosis were 8 times more likely possibility to have C3 category appearance in the Klemetti index (39).

Mostafa et al confirmed many previous studies and found higher CTMI and CTCI values in control groups than osteopenic and osteoporotic groups($p<0.001$) (40). The risk of osteoporotic fractures is different between men and women, and it is higher in women. This is due to the fact that estrogen decreases faster in women of the same age group than in men (40). Therefore, studies generally include women. However, since the disease may be seen in men, they should be included in the study. Men were also included in this study.

Similar to the studies of Yaşar, Basavaraj, Horner and Devlin, Taguchi and Gülşahi, it is found that C1 C2 and C3 classes were examined according to Klemetti index in both DPR and CBCT images in individuals with(MI≤3mm) and without risk of osteoporosis, for both observers frequency distributions were found to be significantly different($p<0.001$) (5,20,29,34,42). In panoramic radiography; for the 1st observer, 91.7% of the patients with C3, 66% of those with C2 and 34.7% of the patients with C1 were found to have osteoporosis risk. In CBCT images; 87.1% of the patients in the C3 category, 65.5% of the patients in the C2 category, and 17.9% of the patients in the C1 category were in the group at risk of osteoporosis. For the second observer, 85.7%, 63.6%, and 39% of the patients respectively with C3, C2, and C1 structures on panoramic radiography were found to have osteoporosis risk while it was found that 84.4%, 61.9%, 38.5% of them had this risk in CBCT images, respectively. In the light of the data that is obtained, the agreement between MCI and CTCI was moderate for the 1st observer (Weighted Kappa Coefficient = 0.669), while it was high for the 2nd observer (Weighted Kappa Coefficient = 0.841).

Horner and Devlin looked at the correlation between DEXA measured from the mandible and BQI and MCI evaluated on panoramic radiographs (41). As a result of the study carried out by two observers, it was concluded that both BQI and MCI indices were significantly correlated with DEXA measurements. Inter-observer agreement was found to be higher in BQI evaluation than MCI evaluation. In this study, the inter-observer agreement was found to be high in terms of evaluations of BQI in both CBCT images and DPR.

In future studies, it will be possible to reach more precise threshold values by providing clearer comparisons by the increase in the number of patients to be included in the studies will also increase the accuracy and validity of the results.

CONCLUSION

As a result of the study, it was found that CBCT and DPR are highly compatible in osteoporosis risk assessment. A threshold value in terms of CTMI was reached in the assessment of this risk. When CBCT is taken for the dental problems, the patient should be evaluated for osteoporosis with the threshold value found in this study. It was demonstrated that the deviation of the threshold value reached on CBCT from the threshold value measured in DPR was very low, it would be correct to say that osteoporosis evaluation can be performed with DPR, which is much more common and cheaper than CBCT evaluation.

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