RESEARCH ARTICLE

The osseous and dental changes of patients with chronic renal failure by CBCT

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Objectives: The aim of the present study was to evaluate the osseous changes of the jaws of patients with chronic renal failure (CRF) by CBCT.

Methods: On CBCT scans obtained from 15 patients with CRF and 15 control patients (7 males and 8 females), the mean was calculated for the antegonial index (AI), mental index (MI), panoramic mandibular index (PMI) and mandibular cortical index (MCI). The MI, AI and PMI, pulp chamber size, number of teeth with pulp calcification and lamina dura loss were compared using the paired *t*-test, and the MCI values were analysed using the χ^2 test.

Results: There were no statistically significant differences in the PMI, MI and AI values in patients with CRF and the control group. With regard to MCI, the cortical margins of the mandible were more porous in patients with CRF than in the control group, and also soft-tissue calcifications, lamina dura loss and radiolucent defects were more common in patients with CRF. There were no statistically significant differences in pulp chamber size and pulp calcifications between patients with CRF and the control group.

Conclusions: Radiographic changes in the jawbones of patients with CRF may be commonly seen. CBCT is a valuable diagnostic tool for the evaluation of osseous findings, pulp chamber, soft-tissue calcifications and MCIs and allows indices measurement in three dimensions without any superposition.

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Introduction

Chronic renal failure (CRF) affects 10% of the population and several changes occur in the oral cavity associated with CRF. Researchers estimate that up to 90% of patients with CRF will show oral symptoms.¹ CRF is associated with alterations in bone and mineral metabolism. Osseous changes owing to CRF may become worse from a combination of various factors such as vitamin D deficiency, hyperparathyroidism, malnutrition, the use of certain drugs or hypogonadism. The manifestations of metabolic renal osteodystrophy of the jaws are bone demineralization, decreased trabeculation, “ground glass” appearance, radiolucent giant cell

lesions (brown tumour), metastatic soft-tissue calcifications, loss of lamina dura, pulpal narrowing and calcification, and periodontal defects.^{2,3}

Dental panoramic radiographs have a long history of examining current dentition, temporomandibular joint, jawbones and related structures, and have been shown in recent clinical studies to play a critical role in the identification and evaluation of patients with low bone mineral density. Mandibular bone quality can be assessed using intraoral radiographs, panoramic radiographs, CBCT, quantitative and dual-energy X-ray absorptiometry.⁴⁻⁸ There are several radiomorphometric indices that use measurements in panoramic radiographs, which have been suggested as possible indicators of decreased value of bone mineral density.⁷⁻⁹ It was shown

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that CBCT can also be used to determine mandibular indexes in several studies.^{5,6,10,11} Panoramic radiography cannot illustrate the buccolingual width and also distorts the images.⁶ CBCT is capable of providing accurate, submillimetre-resolution images in formats allowing three-dimensional visualization of the complexity of the maxillofacial region.

To our knowledge, this was the first study in the literature that evaluates the osseous changes and dental findings of patients with CRF by CBCT. The aim of the present study was to evaluate the mandibular cortical indices (MCIs), mandibular canal diameter, pulp chamber size, pulp calcification, lamina dura loss and soft-tissue calcifications in patients with CRF and in healthy controls.

Methods and materials

Study group

The study consisted of 15 patients with CRF and 15 healthy controls (7 males and 8 females for each of the patient group and control group). The mean age was 31.50 ± 11.16 years (minimum, 15 years; maximum, 48 years) for both patient and control groups. Patients with glomerular filtration rate $>60 \text{ ml min}^{-1}$ were included in the study, and the average time elapsed since entry to dialysis was 39 ± 29.44 months (minimum, 12 months; maximum, 108 months). Patients with anaemia, diabetes mellitus, radiotherapy, alcohol consumption, corticosteroid medication, hyperthyroidism and a history of smoking were not included in the study. New CBCT scans for the healthy control group were not performed. The control group was chosen among the CBCT archive with the same gender and the same age as those of the patient group, and the mean age of the control group was the same as that of the patient group. The study was approved by the ethical committee of the Faculty of Dentistry of Ataturk University, Turkey. Written informed consent was obtained,

and the *pro forma* inventory was completed detailing the patients' names, age, sex and relevant medical history.

Imaging procedures

The CBCT images were taken with a NewTom® 3G (Quantitative Radiology, Verona, Italy) flat panel-based CBCT device. The scanner operated with a maximum output of 110 kV, 15 mAs and 0.16-mm voxel size. The patient was placed in a horizontal position, so that the Frankfort plane was perpendicular to the table, with his/her head within the circular gantry housing the X-ray tube to obtain consistent orientation of the sagittal images. The X-ray tube-detector system performed a 360° rotation around the head of the patient, and the scanning time was 36 s. After the completion of the scan, the patient left the examination room and the clinician performed the primary reconstruction. The QR-NNT v. 2.21 (Quantitative Radiology) software program was used for analyses.

Measurements

On CBCT scans obtained from patients with CRF and healthy controls, the measurements were performed as follows. The measurements used in the present study were modified to CBCT from Ledgerton's classification on panoramic images.^{5,12} The antegonial index (AI), mental index (MI), panoramic mandibular index (PMI) and MCI values were measured in the right and left mandibles of patients with CRF and the healthy controls on CBCT scans. For MI, mandibular cortical thickness was measured on the line that was perpendicular to the bottom of the mandible at the middle of the mental foramen (Figure 1a). The PMI was the ratio of the thickness of the mandibular cortex to the distance between the mental foramen and the inferior mandibular cortex (Figure 1a). The AI was a measurement of cortical width in the region that is anterior to the gonion, at a point that is identified by extending a line of "best fit" on the anterior border of the ascending ramus, down to the lower border of the

Figure 1 The measurements: (a) panoramic mandibular index, mental index, (b) antegonial index and (c) pulp chamber size.

Figure 2 Mandibular cortical index. (a). The endosteal margin of the cortex is even and sharp on both sides; (b) the endosteal margin shows semilunar defects or seems to form endosteal cortical residues on one or both sides; (c) the cortical layer forms heavy endosteal residues and is clearly porous.

mandible (Figure 1b). The MCI was assessed as follows: Class I, the endosteal margin of the cortex is even and sharp on both sides; Class II, the endosteal margin shows semilunar defects or seems to form endosteal cortical residues on one or both sides; Class III, the cortical layer forms heavy endosteal residues and is clearly porous (Figure 2).

The soft-tissue calcifications, pulp calcifications, pulp chamber size and lamina dura were also evaluated for patients with CRF and the controls. For determining soft-tissue calcifications, all of the axial slices were examined in the scanning area, and the detected cases were noted. Soft-tissue calcifications such as osteoma cutis, calcified stylohyoid chain, tonsillolithiasis, sialolithiasis and carotid artery calcifications were noted (Figure 3).

The number of teeth with pulp calcification was noted. The measurement of pulp chamber size was established on 1-mm oblique sagittal sections from mandibular first molars, and a total of four different linear measurements were made for this: (1) horizontal mesiodistal width of the pulp chamber by measuring across the narrowest of the coronal pulp chamber, (2) horizontal mesiodistal width of the teeth at the same level, (3) vertical occlusoapical height of the pulp chamber from the lowest part of the pulp ceiling to the

lowest part of the pulp, (4) continuation of the vertical measurement from the lowest part of the pulp ceiling to the bifurcation. The dimensions of the pulp chamber were calculated as ratio of one-half and three-quarters to determine the proportional degree of reduction in pulp chamber size (Figure 1c).¹³

Additionally, it was also examined whether there were radiolucent lesions (brown tumour) on the jaws (Figure 4).

Statistical analyses

Two observers, who were oral and maxillofacial radiologists with 7 years' experience in CBCT images, performed the measurements and categorizations after providing calibration for each other. The observers established all of the measurements, and the mean values were used to determine the reliability of the study.

Statistical analyses were conducted with SPSS® software (SPSS v. 20.0 for Windows; SPSS Inc., Chicago, IL). The MI, AI and PMI values, pulp chamber size, number of teeth with pulp calcification, and lamina dura loss were evaluated using the paired *t*-test, and the MCI values were analysed using the χ^2 test. Values of $p < 0.05$ were considered to indicate statistical significance.

Figure 3 Soft-tissue calcifications. CAC, carotid artery calcification; OC, osteoma cutis; TL, tonsillolithiasis.

Figure 4 Brown tumour in cross-sectional and panoramic views.

Results

Both patients with CRF and the control group had the same demographics, including age and gender. There were no statistically significant differences between MI, PMI and AI of patients with CRF and that of the healthy controls (Table 1). The MCI of patients with CRF showed more porous texture as is shown in Table 2. Although 26.7% of patients with CRF showed Class III MCI, this ratio was 0% in the control group (Table 2).

There were also no statistically significant differences in the pulp chamber size and number of teeth with pulp calcifications between patients with CRF and those of the control group (Table 1). However the number of teeth with lamina dura loss was higher in patients with CRF ($p < 0.001$) (Table 1).

Also, the soft-tissue calcifications could be detected by CBCT, and there was significant difference in patients

with CRF and the control group, for example, 73% of the patients with CRF had at least one soft-tissue calcification, whereas 33% of the control group had at least one soft-tissue calcification as shown in Table 3.

Also in three of the patients with CRF (20%), radiolucent defects (brown tumour) were detected; however, there were no radiolucent defects on the jaws of the control group (Table 3).

Discussion

Osteoporosis is a progressive bone disease that is characterized by a decrease in bone mass and density. Renal insufficiency is one of the medical disorders that can lead to osteoporosis and renal osteodystrophy. Orofacial features of renal osteodystrophy are bone demineralization, decreased trabeculation, decreased

Table 1 The panoramic mandibular index (PMI), mental index (MI), antegonial index (AI), pulp chamber size, number of teeth with pulp calcification and lamina dura loss in patients with chronic renal failure (CRF) and in the control group

	<i>Patients with CRF</i>		<i>Control group</i>		<i>t^a</i>	<i>p-value</i>
	<i>n</i>	<i>Mean ± SD</i>	<i>n</i>	<i>Mean ± SD</i>		
MI						
Right	15	3.62 ± 0.75	15	3.19 ± 0.69	1.614	0.118
Left	15	3.60 ± 0.73	15	3.26 ± 0.55	1.449	0.158
PMI superior						
Right	15	4.71 ± 0.93	15	5.37 ± 1.30	−1.603	0.120
Left	15	4.60 ± 0.86	15	5.06 ± 0.77	−1.570	0.128
PMI inferior						
Right	15	3.77 ± 0.78	15	4.23 ± 0.86	−1.517	0.140
Left	15	3.63 ± 0.74	15	3.85 ± 0.54	−0.933	0.359
AI						
Right	15	2.43 ± 0.70	15	2.76 ± 0.59	−1.374	0.180
Left	14	2.42 ± 0.56	15	2.87 ± 0.91	−1.567	0.129
Pulp chamber size						
Vertical	12	0.45 ± 0.10	11	0.38 ± 0.72	1.761	0.088
Horizontal	12	0.38 ± 0.06	11	0.37 ± 0.04	0.411	0.685
Pulp calcification	15	0.80 ± 1.20	15	0.60 ± 0.82	0.529	0.601
Lamina dura loss	15	19.66 ± 9.42	15	7.07 ± 6.69	4.224	0 ^a

SD, standard deviation.

^a $p < 0.001$.

Table 2 Mandibular cortical index values of the patients with chronic renal failure (CRF) and the control group

	Class I		Class II		Class III	
	n	%	n	%	n	%
Patients with CRF	7	46.7	4	26.7	4	26.7
Control group	13	86.7	2	13.3	0	0

thickness of cortical bone, ground glass appearance of bone, metastatic soft-tissue calcification, radiolucent giant cell and fibrocystic lesions, lytic areas of bone, jaw fracture and abnormal bone healing.³

Panoramic radiography is useful in showing the effect of CRF on bones such as mandibular cortical bone resorption and changes in the trabecular bone pattern yielding a ground glass appearance.¹⁴ In this respect, the PMI, MI and MCI are thought to be the panoramic radiography parameters for the prediction of osteoporosis.^{5,15} Some researchers demonstrated that mandibular cortical width has better efficacy in detecting osteoporosis on panoramic images.^{5,8,15} However, some researchers stated that PMI and MI should not be used to assess patients' status regarding osteoporosis.^{5,16} Even if consensus cannot be reached between examiners, a mandibular cortical bone thickness of approximately 3 mm and a severely eroded cortex (Type III classification) are strong indicators for the investigation of osteoporosis.^{17,18} Dagistan and Bilge¹⁵ mentioned that MI, PMI and AI values are smaller in osteoporotic men; however, in another study, it was mentioned that they were not altered in osteoporotic females.¹⁶ It was also found that panoramic radiographs of patients with CRF show a loss of cortical bone at the mandibular angle.¹⁴ However, in the present study, we did not find any statistically significant differences between the PI, PMI and AI values of patients with CRF and control groups except MCI. Henriques *et al*¹⁸ also did not find significant differences in MI and PMI values of patients with renal failure; however, they found the MCI to be more porous in patients with renal failure similar to our results.

In recent studies, it was mentioned that CBCT images can be used in the evaluation of mandibular indices.^{5,6,10,11} This is the first CBCT study associated with MCI measurements and other osseous and dental findings in patients with CRF. CBCT does not magnify or overlap neighbouring structures, which are inherent problems in panoramic radiography. CBCT allows images to be acquired using a low dose of radiation, shorter patient examination time and lower costs than does CT, and its routine use is feasible for oral and maxillofacial procedures. Panoramic radiography cannot

illustrate the width of the buccolingual alveolar ridge and also distorts the images.⁶

Calcification of soft-tissue structures in the head and neck can present as physiological or pathological mineralization.¹⁹ Calcium absorption in the intestines is diminished early in renal failure because the kidneys cannot convert vitamin D to its active form. CRF is aetiologically related to altered balance in blood calcium and is characterized by laboratory abnormalities (*i.e.* serum calcium and phosphate, parathormone and/or vitamin D), abnormalities in bone turnover, mineralization or volume, and vascular or other soft-tissue calcification.^{20,21} The prevalence of vascular calcifications that cause cardiovascular diseases is the main cause of mortality among patients with CRF.¹⁷

In the present study, we have found that soft-tissue calcification was more common in patients with CRF than in the control group, and could be detected easily on CBCT images. Some calcifications can be detected at panoramic radiography, sometimes owing to the proximity of soft-tissue structures to the focal trough. However, these images are inherently planar and two-dimensional, making localization and diagnosis problematic. Conventional two-dimensional imaging is likely to result in relatively low diagnostic success, especially in cases where relatively small calcifications are present or are superimposed on anatomical structures. In such cases, a second radiological two-dimensional plane must be obtained. With the increasing use of CBCT imaging in dentistry, the incidental discovery of these calcifications is likely to increase.²² In addition, CBCT imaging provides images in the third dimension, which facilitates precise localization.

The literature has documented pulpal narrowing and calcification as well as delayed or altered eruption in patients with CRF.^{1-3,13,23} Pulpal calcification is common in patients with CRF and transplanted patients. A strong correlation between the chronicity of the renal disease and the pulp narrowing has been observed in the premolar and molar teeth of such patients.³ Dental pulp calcification may occur in response to both local and systemic factors. Local factors include caries, cavity preparation, restorations and excessive forces. Systemic factors include hypercalcaemia, gout and renal failure.¹³ Pulp calcifications are not clinically discernible. Pulpal calcification and narrowing also can be easily diagnosed using conventional dental radiographic methods such as periapical and panoramic radiography.²³ In general, calcifications of the pulp can be demonstrated more readily by use of bitewing and periapical radiographs. Comparison of periapical and bitewing radiographs showed no significant difference in the diagnosis of pulp calcification.²³ CBCT, which was also used in the present study, allows practitioners to measure distances with real dimensions and without superimposition or distortion.

However, there is conflicting literature on the association of the presence of pulp calcification and systemic disturbance. Some researchers mentioned a relationship,^{24,25} while some mentioned no association.^{23,26} In the present study, no statistically significant differences in

Table 3 The number of brown tumour and soft tissue calcifications in patients with chronic renal failure (CRF) and the control group

	CRF patients		Control group	
	n	%	n	%
Brown tumour	3	20	0	0
Soft-tissue calcification (at least one)	11	73	5	33

the number of teeth with pulp calcification and pulpal narrowing ratio between patients with CRF and those of the control group were found.

Lamina dura is bundle bone that lies adjacent to the periodontal ligament, lining the tooth socket. On X-ray, lamina dura will appear as a radio-opaque line surrounding the tooth root. Total or partial lamina dura loss is one of the dental radiographic findings in patients with CRF.^{2,3,25,27} In the present study, we have also found that the number of teeth with lamina dura loss was statistically higher in patients with CRF than in the control group, which is in agreement with the literature. It was mentioned that in panoramic and periapical radiographs, bone craters, lamina dura and periodontal bone level evaluation is limited by the superposition of the adjacent anatomical structures and projection geometry.²⁸ However, in a recent study it was mentioned that bone quality and the details of lamina dura scored better on digital intraoral radiography than on CBCT.²⁹

Secondary hyperparathyroidism is a frequent complication of CRF, and brown tumours are seen in 1.50–1.75% of patients with secondary hyperparathyroidism.³⁰ These tumours are also associated with CRF and are being reported with increasing frequency.^{25,30,31} Brown tumours result from the destruction of local bone occurring especially in regions where bone resorption is particularly rapid with haemorrhage and reparative granulation tissue containing giant multinucleated cells replace the normal marrow content.³⁰ The

majority of brown tumour cases reported the jaws as the main sites of occurrence.³² In tomography scans, brown tumour shows an osseous mass, with no cortical disruption, no periosteal reaction, a heterogeneous centre and areas that suggest cysts.³³ Symptoms result from the considerable dimensions of the lesion and its localization. However, in most cases, brown tumours in the jaws are not painful. In the present study, there were three patients with radiolucent lesions in the jaws, and they were painless. They appeared as regular, limited, lytic, hypodense areas with no cortical expansion or perforation on CBCT images.

In conclusion, since signs and symptoms of renal disease can be seen in the intraoral region, the dentist, if aware of these problems, can play an important role in the diagnosis, overall health and treatment of the patient. Radiographic changes in the jawbones and teeth of patients with CRF may be commonly seen. In the present study, there were no statistically significant alterations in the MI, PMI and AI of patients with CRF except in the MCI. Also, the pulp chamber was not affected in patients with CRF. However, soft-tissue calcifications were common in patients with CRF. CBCT is a valuable diagnostic tool for the evaluation of osseous findings, pulp chamber, soft-tissue calcifications and MCIs, and allows indices measurement in three dimensions without any superposition. The limitations of this study included the small sample size, and further studies with a larger sample are required.

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