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Original Article

Jaw bone changes in panoramic radiography in patients with hyperparathyroidism

Maryam Mohammadi[1], **Saeed Alinejad**[1], **Farida Abesi**[2*]

[1]Department of Biology and Laboratory Sciences, Babol Branch, Islamic Azad University, Babol, Iran
[2]Dental Materials Research Center, Department of Oral and Maxillofacial Radiology, Dental Faculty, Babol University of Medical Sciences, Mazandaran, Iran

***Corresponding Author:** Farida Abesi, Email: faridaabesi@yahoo.fr

Abstract

Background and aims: The current investigation aimed to evaluate jaw bone changes, and compare the presence of gonial cortex bone thickness, mental index (MI), lamina dura (LD), lower dental canal, and bone density in panoramic radiography, in patients with hyperparathyroidism.

Methods: The present cross-sectional descriptive-analytical study was performed on 17 healthy individuals and 17 patients who suffered from resorptive hypercalciuria in the dialysis center of Shahid Beheshti hospital in Babol in 2018. If patients had two or more decayed teeth, they were referred to a specialized maxillofacial clinic by the dentist for free panoramic imaging. Mandibular cortical index, LD, bone change, mandibular resorption (MR), and general cortical indices underwent examination.

Results: The mean age of the control and case groups was 36.58 ± 11.81 years and 40.23 ± 14.32 years, respectively ($P = 0.424$). In addition, the mean MI was 4.27 ± 0.87 and 2.98 ± 0.75 in the control and case groups, respectively ($P < 0.001$). Based on the results, the mean gonion region's cortical bone thickness was 0.93 ± 0.23 and 1.09 ± 0.24 in the case and control groups, respectively ($P < 0.001$). Further, bone changes ($P = 0.036$) and MR ($P = 0.017$) were significantly different in the case and control groups. However, LD vision showed no significant difference in the hyperparathyroidism and the control groups ($P = 0.141$).

Conclusion: The results demonstrated a decrease in the thickness of the cortical bone in the guinea pig, mental region, and lack of dental canal in resorptive hypercalciuria compared to healthy individuals.

Keywords: Jaw, Panoramic radiography, Bone changes, Radiography, Hyperparathyroidism

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Introduction

Chronic renal failure (CRF) is a progressive and irreversible loss of kidney function (1). The kidney has an important function in the activation of vitamin D. During renal failure, hypocalcemia occurs due to phosphate retention and excretion of calcium by the kidneys. Such a condition stimulates parathyroid hormone secretion and leads to secondary hyperparathyroidism (2,3). CRF causes various complications, of which hyperparathyroidism is one of the most common. Accordingly, about 82% of dialysis patients develop secondary hyperparathyroidism (4). Complications of secondary hyperparathyroidism include pruritus, thirst, headache, muscle weakness, bone pain, joint pain, abdominal pain, mood swings or depression, red-eye syndrome, vascular calcification, brown tumors in the mandible, brown tumors in the bones of the limbs, low bone mineral density, and brittle bone fractures were noted (5). There have been numerous dental complications reported following secondary hyperparathyroidism. Researchers estimated that up to 90% of patients show oral symptoms (6). These symptoms include bone demineralization, increased bone density, frosted glass view of bone, decreased cortical bone thickness, increased bone volume due to increased coarse trabeculae of spongy bone tissue, giant tuberculous lesions, abnormal bone repair after tooth extraction, metastatic calcification of soft tissue, and jaw fracture (7). Furthermore, dental manifestations are observed in some patients, such as enamel hypoplasia in deciduous and permanent teeth, loss of dorsal lamina, periodontal ligament dilation, severe periodontal destruction, loosening of teeth, and calcification or narrowing of the dental pulp. In severe cases of hyperparathyroidism, the cortical plates become thinner, and the lamina dura (LD) around the teeth' roots may not be found on the radiograph (8). There have been reports of jaw bone involvement due to secondary hyperparathyroidism in patients who suffered from renal insufficiency, including cases of neuralgia reported by other researchers (9-13). Panoramic radiography is a technique for obtaining a single tomographic image of pink structures, including maxillary and mandibular dental arches and surrounding structures such as the maxillary sinus (14). The mentioned method is a standard type of tomography based on the radiation source's simultaneous

movement and the image receiver around a central point or plane called the image layer on which the object is placed (15). Panoramic radiography can be used to assess trauma, developmental abnormalities, alveolar bone examination, large peripheral jaw lesions, and assessment of tooth development in the mixed dental period. Some advantages of panoramic radiography are the low cost, the low radiation dose to the patient, comprehensive coverage of the facial bones and teeth, short imaging time, patient perception of panoramic films, and availability (16). The present study, through recruitment of patients who suffered from hyperparathyroidism, attempted to evaluate the jaw bone changes, including comparing the presence of gonial cortex bone thickness, mental index (MI) index, LD, lower dental canal, and bone density, in panoramic radiography.

Materials and Methods

Study groups

The current cross-sectional descriptive-analytical study was conducted on 17 healthy individuals and 17 patients with hyperparathyroidism in the Dialysis Center of Shahid Beheshti Hospital, Babol, Iran, between 2018 and 2019. Sampling was performed by the convenience sampling method, and the sample size was calculated using previous articles (17) in the G*Power software by employing an independent t-test with a type I error of 0.05, a power of 0.95, and an effect size of 1.45. A total of 14 individuals per group were calculated, and 17 individuals were selected for each group, considering a potential dropout rate.

The present study was approved by the Ethics Committee of the Medical School of Islamic Azad University, Babol branch, and conscious consent was also obtained from all patients. In addition, the demographic features of subjects, including name, age, gender, and relevant medical history, were recorded. Patients were referred to a specialized maxillofacial clinic by the dentist for free panoramic imaging if they had two or more decayed teeth. Patients with a history of anemia, diabetes, head and neck radiotherapy, history of alcohol and corticosteroids, pregnancy, tonsillitis, and metabolic bone diseases, such as thyroid disorders, hyperthyroidism, Addison's disease, and Cushing's disease, were excluded from the investigation. A total of 34 dental panoramic radiographic images with the best quality and resolution of mandibular cortical bone has been collected from the present database of a maxillofacial radiology branch.

Imaging

The panoramic radiographs were obtained with panoramic machines (Soredex, Cranex Novus, Tuusula, Finland; 70 kV, 10 mA for 8 s exposure time). All units of panoramic radiographs were imported into the Photo J software program (ImageJ; US Country-wide Institutes of Health, Bethesda, MD).

The indicators studied in this research included:

- Mental Index: Thickness of the lower mandibular cortex in the chin hole area
- Mandibular cortical index (MCI): Morphological form of the mandibular lower cortex in the chin hole area, which exists in three forms as follows:
  C1: The endosteal side of the cortex is marked at both edges.
  C2: The endosteal side of the cortex is observed in each semicircular defect.
  C3: There is a severe defect in the observed endosteal, and the cortex has many pores.
- Cancellous bone changes are divided into two granular and healthy categories.
- Manual cortical resorption
- Canal.

About 10% of radiographs were re-examined at 6-week intervals to prevent probable data errors.

All measurements were independently performed by oral radiologists. The observers were blinded to the medical popularity of the sufferers. Prior to taking look at the panoramic images, the observers had been calibrated by re-evaluating 20% of the dental panoramic radiography images. The mean values of the size of the two observers were used because of the final facts within the statistical analysis. In cases where there were inconsistencies among the 2 observers within the MCI assessment, a consensus changed into installed, and the third observer changed into consulted when necessary.

Statistical analyses

The data were analyzed using statistical software (SPSS, version 24). Means and standard deviations, as well as frequencies and frequency percentages, were used to describe quantitative and qualitative data, respectively. In addition, Fisher's exact test was employed to compare the frequency of qualitative variables in both case and control groups. Finally, the normality of the data was confirmed using the Shapiro-Wilk test, and then the independent t-test was utilized to compare the quantitative variables between the two control and case groups. The significance level of the tests was considered to be 0.05.

Results

A total of 34 panoramic images of patients with hyperparathyroidism were examined (17 patients with an average age of 36 years [between 28 and 60 years] and 17 healthy individuals with an average age of 38 years [between 26 and 60 years]) in the oral and maxillofacial radiology clinic. Both hyperparathyroidism and control groups had demographic characteristics, including age and gender. Figure 1 shows the distribution of quantity and frequency of individuals' status with MI, bone changes, thickness, MR, and LD.

Table 1 provides the distribution and comparison of the distribution of the individuals' status based on their gender. In terms of gender, there was no significant difference between the two control and case groups

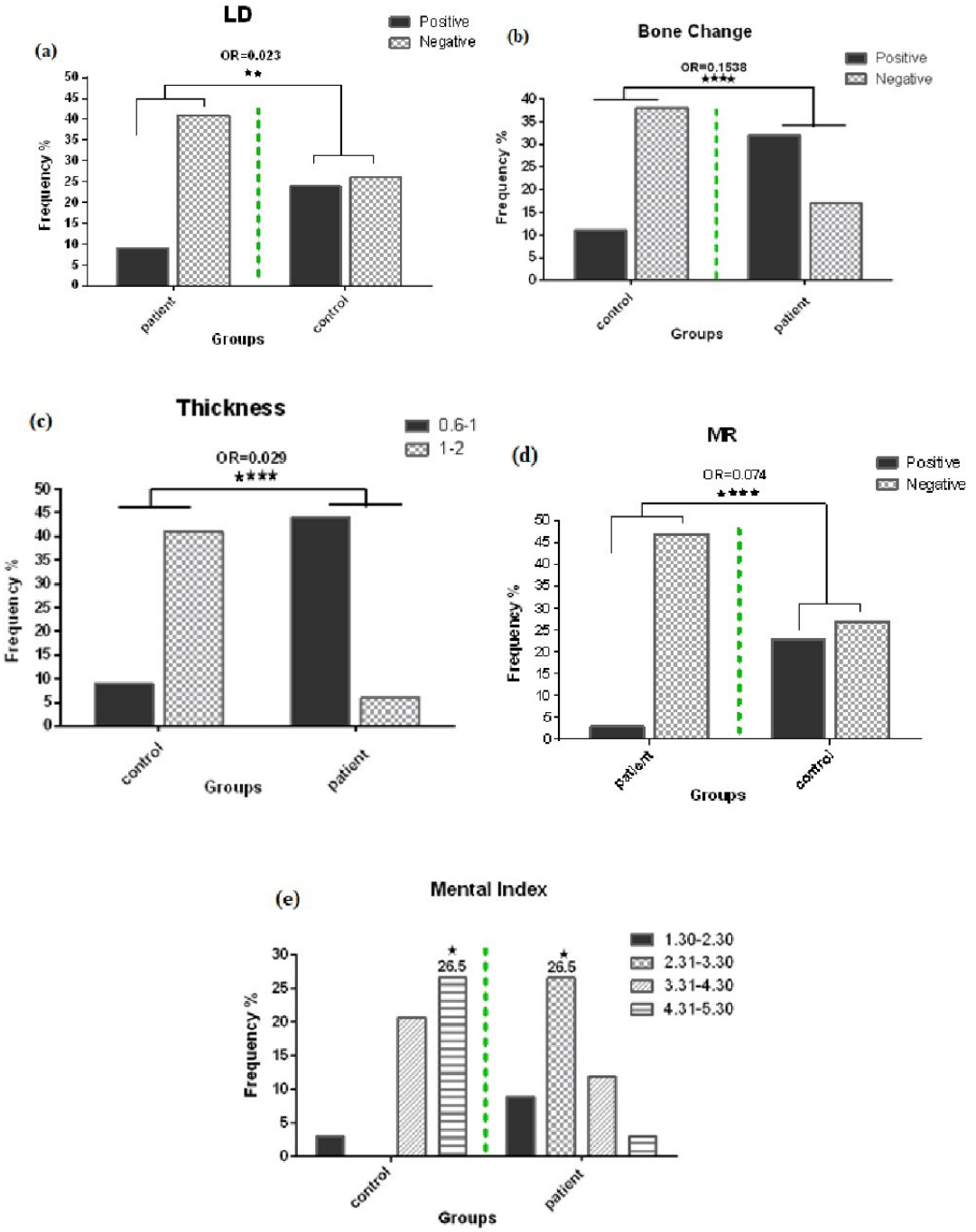

Figure 1. Distribution of quantity and frequency percentage of individuals' status with (a) LD, (b) bone change, (c) thickness, (d) MR, and (e) MI parameters.
Note. LD: Lamina dura; MR: Mandibular resorption; MI: Mental index

Table 1. Distribution of demographic variables in individuals' status

Value		Control (n = 17)	Case (n = 17)	*P* value
Gender	Woman	4 (23.5%)	6 (35.2%)	0.707
	Man	13 (76.5%)	11 (64.8%)	
Age (mean ± SD)		36.58 ± 11.81	40.23 ± 14.32	0.424

Note. SD: Standard deviation.

($P = 0.707$). The mean age in the control and case groups was 36.58 ± 11.81 and 40.23 ± 14.32, respectively. No statistically significant difference was found between the ages of these two groups (Table 2).

Table 2 presents the frequency distribution and frequency percentage comparison of individuals' status, MI, and thickness. The highest value of the MI was 4.31–5.30 in the control group and 2.31–3.30 in the patient

Table 2. Distribution of frequency and frequency percentage of individuals' status, MI, and thickness

Value		Control (n = 17)	Case (n = 17)	*P* value
MI	1.30–30.30	1 (5.9%)	12 (70.6%)	< 0.001
	3.31–5.30	16 (94.1%)	5 (29.4%)	
Thickness	0.6–1	3 (8.8%)	15 (44.1%)	< 0.001
	1–2	14 (41.2%)	2 (5.9%)	

Note. MI: Mental index.

group. The comparison of panoramic radiographic findings in patients with hyperparathyroidism in the healthy group revealed a significant difference in these two groups in terms of MI ($P<0.001$). Moreover, Table 2 summarizes the frequency distribution and frequency percentage comparison of individuals' status and thickness. The highest value was 2–1 in the control group and 1–0.6 in the case group. The comparison of panoramic radiographic findings demonstrated a significant difference in the thickness index in these two groups ($P<0.001$). Table 2 presents the results of the frequency distribution and frequency percentage comparison of an individual's status, LD, MR, and bone change. The highest amount of bone change was negative in the control group but positive in the case group. Based on the comparison of panoramic radiographic findings, a significant difference was found between the bone change indexes in these two groups ($P=0.036$). In addition, the frequency distribution and frequency percentage comparison of individuals' status and MR based on panoramic radiographic findings showed a significant difference in the MR index between these two groups ($P=0.017$). Furthermore, the frequency distribution and frequency percentage comparison of individuals and LD status revealed that the highest amount was negative in both patient and healthy groups. A comparison of panoramic radiographic findings indicated no significant difference in the LD index in the two study groups ($P=0.141$, Table 3).

MI, the thickness of the gonion region's cortical bone, the view of the lower dental canal, changes in bone density, and the appearance of LD were examined in panoramic radiography (Figure 2). The mean MI was 4.27 ± 0.87 in the case group and 2.98 ± 0.75 in the control group ($P<0.001$). The mean gonion region's cortical bone thickness was 1.09 ± 0.24 and 0.93 ± 0.23 in the control and case groups, respectively ($P<0.001$). Moreover, positive bone changes ($P=0.036$) and MR ($P=0.017$) were significantly different in the case and control groups. However, in the hyperparathyroidism and control groups, LD vision showed no significant difference ($P=0.141$, Tables 2–3).

Discussion

Excess parathyroid hormone secretion leads to hyperparathyroidism with primary, secondary, and tertiary forms. The interaction of parathyroid glands, bones, and intestines is necessary for the formation of minerals and plays the main role in bone disorders (18). Secondary hyperparathyroidism is caused by the effects of chronic kidney disease (19). The clinical symptoms and signs vary in chronic kidney disease patients, including increased blood pressure, metabolic acidosis, defects in erythropoietin production, and effects on mineral and bone metabolism because of a reduction in renal function (20). The kidney has important endocrine functions in vitamin D production and calcium and phosphate balance. In chronic kidney disease, because of the decreased endocrine function of the kidney, activation of vitamin D into its active form decreases, and the inadequate excretion of phosphate can be observed, leading to phosphate overload, the formation of insoluble calcium phosphate, and hypocalcemia (21). Regarding the results of hypocalcemia, parathyroid hormone secretion increased and led to the over-activation of the parathyroid gland, secondary hyperparathyroidism; to compensate for calcium deficiency, parathyroid hormone caused calcium levels in serum to increase by releasing from bones via the activation of osteoclasts, the receptor activator of nuclear factor-kappa B and its ligand system (22,23), and reabsorption of calcium from the kidney, decreasing serum level of phosphate (24). The disorder of calcium, phosphate, parathyroid hormone, and vitamin D levels and their function on bone turnover metabolism and mineralization is called renal osteodystrophy (25). The jaw bone is one of the important bones in oral health. Oral health is an important component of a person's general health and quality of life. The jaw bone is important for tooth germs (26). In osteoporosis, the affected bones, including the collar and the mandible bones, are the most affected site, and cortical bone resorption, loss of LD around the teeth, and trabecular bone alterations are among the most common radiological observations (27). Therefore, the MI and MCI can be appropriate parameters to evaluate changes in the basal cortical bone in the mandible. On the other hand, radiographically is the most common approach for oral cavity and jaw condition investigation (16,28), and due to the common use of panoramic radiographs by dentists, they may be the first clinicians to diagnose bone-related disease signs (29). In this study, jaw bone changes in panoramic radiography in patients with hyperparathyroidism underwent investigation. Bone resorptions and calcifications can be easily determined in panoramic radiograms.

The comparison of panoramic radiographic findings in the patient group with hyperparathyroidism and healthy controls showed a significant difference in the mental, MR, bone density change, and thickness of the gonion regions' cortical bone indexes. However, a comparison of panoramic radiographic findings revealed no significant difference in the LD indexes in both groups of our study. In line with our results, in a study on 59 cases, including 39 hyperparathyroidism and 20 control,

Table 3. Distribution of frequency and frequency percentage of individuals' status, LD, MR, and bone change

Value		Case (n=17)	Control (n=17)	*P* value
LD	Negative	14 (41.2%)	9 (26.5%)	0.141
	Positive	3 (8.8%)	8 (23.5%)	
MR	Right	8 (47%)	1 (5.8%)	0.017
	Left	8 (23.5%)	3 (17%)	
Bone change	Negative	6 (17.6%)	13 (38.2%)	0.036
	Positive	11 (32.4%)	4 (11.8%)	

Note. LD: Lamina dura; MR: Mandibular resorption.

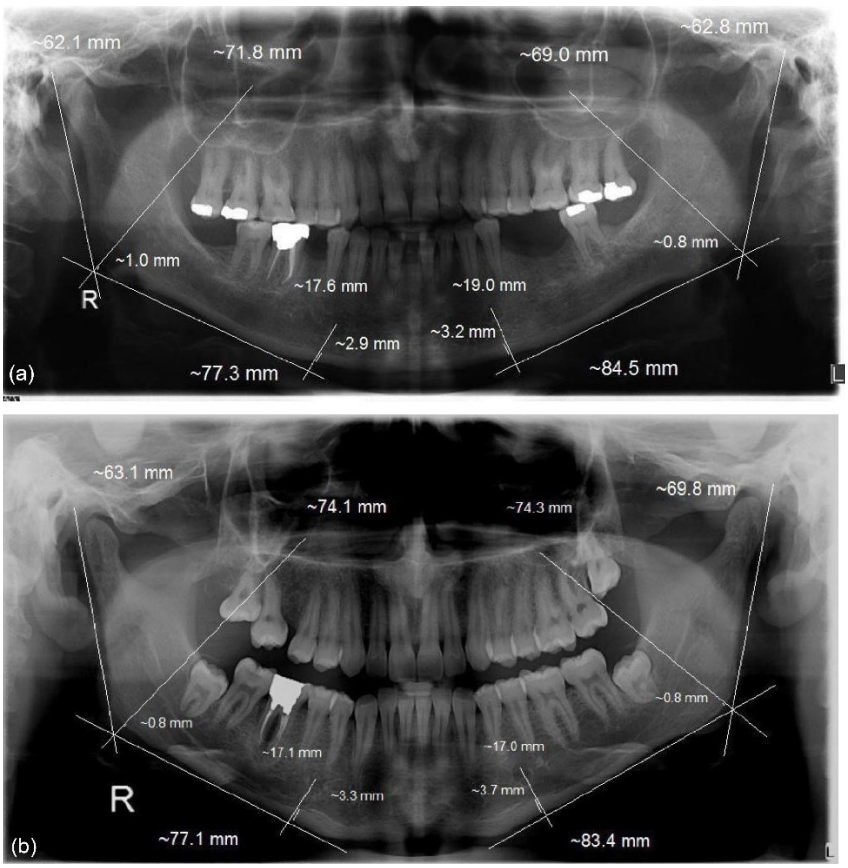

Figure 2. Panoramic radiography: (a) Panoramic radiography of the patient group and (b) panoramic radiography of the control group

gonial cortical bone thickness reduction was observed in the panoramic radiographs of the patient group (30). Moreover, the thinner gonial cortical bone was found in CRF patients in comparison with healthy individuals (31). In addition, in systemic osteoporosis patients, the gonial cortical bone thickness was reported to be thinner (< 1 mm) in comparison with healthy cases (32). In the study by Dagistan et al, the gonial cortical bone thickness was thinner in patients with renal failure compared to the control group (33), which conforms to the results of the present study. Ledgerton et al reported that among the radio-morphometric analyses, the MI has excellent reliability and repeatability for evaluating the bone quality of the oral cavity (34). These data indicated that patients are more likely to degenerate in the gonion region. Consistent with our findings, the results of Dagistan et al confirmed a significant difference in the thickness of the cortical bone in the gonion region between healthy and patient individuals, indicating that patients are more likely to degenerate in the gonion region (33).

LD is a cortical bone that exists around the roots of the teeth. In this study, there was no significant difference in the detection of LD in healthy controls and patient groups, and in the study of Çağlayan et al, LD was absent in people with kidney failure than in healthy people (13). Additionally, in a study by Chatterjee et al, the jaw bone trabecular structural changes were found as a result of osteoporosis (35). It can be concluded that hormonal changes due to aging or various diseases such as hyperparathyroidism can affect the structure of the jaw bone. The results of this study also showed that drug therapies with bisphosphonates may have a protective effect on these changes (35). There was a significant correlation between the morphological changes caused by secondary hyperparathyroidism in the hand and jaw bones in the study by Henriques et al (30). Nevertheless, in some studies, little or no impact on the jaw bones has been reported after aging and osteoporosis. Esteves et al evaluated the effect of estrogen deficiency on the maxilla, mandible, and tibia after 60, 90, and 120 days. The tibia demonstrated osteoporotic changes after the 60-day mark, while no jaw bone exhibited any influences after 120 days (36). The reasons for the conflicting results include the difference between the methods studied for evaluation of the bone changes, the number of studied samples, and the type of sample (animals or humans).

This study had some limitations. Due to the selected inclusion and exclusion criteria, the number participants (N = 34) was relatively low. In addition, our study design included just one assessment time point.

Conclusion

In this study, in hyperparathyroidism compared to healthy individuals, a decrease was observed in the thickness of the cortical bone in the guinea pig, mental region, and lack of dental canal. Therefore, dentists can play a role in the early diagnosis of bone abnormalities that occur as a result of hormonal changes or aging.

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Authors' Contribution
Conceptualization: Maryam Mohammadi, Farida Abesi.
Data curation: Maryam Mohammadi, Farida Abesi.
Formal analysis: Maryam Mohammadi, Farida Abesi.
Funding acquisition: Maryam Mohammadi, Farida Abesi.
Investigation: Maryam Mohammadi, Farida Abesi.
Methodology: Maryam Mohammadi, Farida Abesi.
Project administration: Maryam Mohammadi, Farida Abesi.
Resources: Maryam Mohammadi, Farida Abesi.
Software: Maryam Mohammadi, Farida Abesi.
Supervision: Maryam Mohammadi, Farida Abesi.
Validation: Maryam Mohammadi, Farida Abesi.
Visualization: Maryam Mohammadi, Farida Abesi.
Writing–original draft: Saeed Alinejad.
Writing–review & editing: Saeed Alinejad.

Competing Interests
The authors declare that there is no conflict of interests.

Ethical Approval
Ethical considerations in this study included obtaining permission from the Ethics Committee of the Islamic Azad University of Babol (IR.IAU.SARI.REC.1398.034) and obtaining written consent from the participants for contributing to the study.

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References
1. Kakitapalli Y, Ampolu J, Madasu SD, Sai Kumar MLS. Detailed review of chronic kidney disease. Kidney Dis (Basel). 2020;6(2):85-91. doi: 10.1159/000504622.
2. Gomes do Nascimento MA, Marques-Soares MS, Chimenos-Küstner E, Monteiro Dutra D, Lopes Cavalcanti R. Oral symptoms and oral health in patients with chronic kidney disease. Rev Gaúch Odontol. 2018;66(2):160-5. doi: 10.1590/1981-86372018000200093436.
3. Raubenheimer EJ, Noffke CE, Hendrik HD. Chronic kidney disease-mineral bone disorder: an update on the pathology and cranial manifestations. J Oral Pathol Med. 2015;44(4):239-43. doi: 10.1111/jop.12176.
4. Hyder R, Sprague SM. Secondary hyperparathyroidism in a patient with CKD. Clin J Am Soc Nephrol. 2020;15(7):1041-3. doi: 10.2215/cjn.13411119.
5. Almquist M, Isaksson E, Clyne N. The treatment of renal hyperparathyroidism. Endocr Relat Cancer. 2020;27(1):R21-34. doi: 10.1530/erc-19-0284.
6. de la Rosa García E, Mondragón Padilla A, Aranda Romo S, Bustamante Ramírez MA. Oral mucosa symptoms, signs and lesions, in end stage renal disease and non-end stage renal disease diabetic patients. Med Oral Patol Oral Cir Bucal. 2006;11(6):E467-73.
7. Pakfetrat A, Dalirsani Z, Anbiaee N, Saghafi S, Modarres Mousavy S. Marked enlargement of jaws in a patient with secondary hyperparathyroidism: a case report. J Mashhad Dent Sch. 2016;40(4):1-2. doi: 10.22038/jmds.2016.6945.
8. White SC, Pharoah MJ. Oral Radiology-E-Book: Principles and Interpretation. Elsevier Health Sciences; 2014.
9. Movahedian B, Razavi SM, Hasheminia D, Rezaei M. Simultaneous maxillary and mandibular brown tumors in secondary hyperparathyroidism: a case report. Dent Res J. 2009;5(1):41-5.
10. Jafari-Pozve N, Ataie-Khorasgani M, Jafari-Pozve S, Ataie-Khorasgani M. Maxillofacial brown tumors in secondary hyperparathyroidism: a case report and literature review. J Res Med Sci. 2014;19(11):1099-102.
11. Mardani S, Tamadon MR, Shahbazian H, Beladi Mousavi SS, Ardalan MR, Nasri H. Aggressive jaw brown tumor in a 28-year-old man with long-lasted chronic kidney disease. J Parathyr Dis. 2015;3(1):8-9.
12. Dagistan S, Bilge OM. Comparison of antegonial index, mental index, panoramic mandibular index and mandibular cortical index values in the panoramic radiographs of normal males and male patients with osteoporosis. Dentomaxillofac Radiol. 2010;39(5):290-4. doi: 10.1259/dmfr/46589325.
13. Çağlayan F, Dağistan S, Keleş M. The osseous and dental changes of patients with chronic renal failure by CBCT. Dentomaxillofac Radiol. 2015;44(5):20140398. doi: 10.1259/dmfr.20140398.
14. Choi JW. Assessment of panoramic radiography as a national oral examination tool: review of the literature. Imaging Sci Dent. 2011;41(1):1-6. doi: 10.5624/isd.2011.41.1.1.
15. Yeung AW, Mozos I. The innovative and sustainable use of dental panoramic radiographs for the detection of osteoporosis. Int J Environ Res Public Health. 2020;17(7):2449. doi: 10.3390/ijerph17072449.
16. Awad EA, Al-Dharrab A. Panoramic radiographic examination: a survey of 271 edentulous patients. Int J Prosthodont. 2011;24(1):55-7.
17. Ghapanchi J, Haghnegahdar AA, Faghih M, Rezazadeh F, Derafshi R, Farzin M, et al. Evaluation of mandibular inferior cortex changes in patients candidate for liver and kidney transplantation using panoramic view. J Nephropathol. 2017;6(4):317-23. doi: 10.15171/jnp.2017.51.
18. Bilezikian JP, Bandeira L, Khan A, Cusano NE. Hyperparathyroidism. Lancet. 2018;391(10116):168-78. doi: 10.1016/s0140-6736(17)31430-7.
19. Lu CL, Yeih DF, Hou YC, Jow GM, Li ZY, Liu WC, et al. The emerging role of nutritional vitamin D in secondary hyperparathyroidism in CKD. Nutrients. 2018;10(12):1890. doi: 10.3390/nu10121890.
20. Yuen NK, Ananthakrishnan S, Campbell MJ. Hyperparathyroidism of renal disease. Perm J. 2016;20(3):15-127. doi: 10.7812/tpp/15-127.
21. Kiela PR, Ghishan FK. Molecular mechanisms of intestinal transport of calcium, phosphate, and magnesium. In: Said HM, ed. Physiology of the Gastrointestinal Tract. 6th ed. Academic Press; 2018. p. 1405-49. doi: 10.1016/b978-0-12-809954-4.00059-1.
22. Slootweg PJ. Bone diseases of the jaws. Int J Dent. 2010;2010:702314. doi: 10.1155/2010/702314.
23. Fathi Maroufi N, Ghorbanihaghjo A, Sayyah Melli M, Vaezi M, Hekmati Azar Mehrabani Z, Bannazadeh Amirkhiz M, et al. Effects of high and low doses of folic acid on the soluble receptor activator of nuclear factor-kappa B ligand/osteoprotegerin ratio during pregnancy. Iran J Public Health. 2017;46(4):517-24.
24. Lee M, Partridge NC. Parathyroid hormone signaling in bone and kidney. Curr Opin Nephrol Hypertens. 2009;18(4):298-302. doi: 10.1097/MNH.0b013e32832c2264.
25. Khan M, Sharma S. Physiology, parathyroid hormone (PTH). In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2018.
26. Tsao C, Darby I, Ebeling PR, Walsh K, O'Brien-Simpson N, Reynolds E, et al. Oral health risk factors for bisphosphonate-associated jaw osteonecrosis. J Oral Maxillofac Surg. 2013;71(8):1360-6. doi: 10.1016/j.joms.2013.02.016.
27. Hinchy NV, Jayaprakash V, Rossitto RA, Anders PL, Korff KC, Canallatos P, et al. Osteonecrosis of the jaw - prevention and treatment strategies for oral health professionals. Oral Oncol. 2013;49(9):878-86. doi: 10.1016/j.

oraloncology.2013.06.008.
28. Annex D, United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation. New York: United Nations; 2010.
29. Savic Pavicin I, Dumancic J, Jukic T, Badel T, Badanjak A. Digital orthopantomograms in osteoporosis detection: mandibular density and mandibular radiographic indices as skeletal BMD predictors. Dentomaxillofac Radiol. 2014;43(7):20130366. doi: 10.1259/dmfr.20130366.
30. Henriques JC, de Melo Castilho JC, Jacobs R, Amorim JB, Rosa RR, Matai CV. Correlation between hand/wrist and panoramic radiographs in severe secondary hyperparathyroidism. Clin Oral Investig. 2013;17(6):1611-7. doi: 10.1007/s00784-012-0842-x.
31. Bras J, van Ooij CP, Abraham-Inpijn L, Kusen GJ, Wilmink JM. Radiographic interpretation of the mandibular angular cortex: A diagnostic tool in metabolic bone loss. Part I. Normal state. Oral Surg Oral Med Oral Pathol. 1982;53(5):541-5. doi: 10.1016/0030-4220(82)90473-x.
32. El-Kishawi AM, El-Nahas AM. Renal osteodystrophy: review of the disease and its treatment. Saudi J Kidney Dis Transpl. 2006;17(3):373-82.
33. Dagistan S, Miloglu O, Caglayan F. Changes in jawbones of male patients with chronic renal failure on digital panoramic radiographs. Eur J Dent. 2016;10(1):64-8. doi: 10.4103/1305-7456.175699.
34. Ledgerton D, Horner K, Devlin H, Worthington H. Radiomorphometric indices of the mandible in a British female population. Dentomaxillofac Radiol. 1999;28(3):173-81. doi: 10.1038/sj/dmfr/4600435.
35. Chatterjee M, Faot F, Correa C, Kerckhofs J, Vandamme K. Is the jaw bone micro-structure altered in response to osteoporosis and bisphosphonate treatment? A micro-CT analysis. Int J Mol Sci. 2021;22(12):6559. doi: 10.3390/ijms22126559.
36. Esteves CM, Moraes RM, Gomes FC, Marcondes MS, Lima GM, Anbinder AL. Ovariectomy-associated changes in interradicular septum and in tibia metaphysis in different observation periods in rats. Pathol Res Pract. 2015;211(2):125-9. doi: 10.1016/j.prp.2014.11.015.